

(20242Q) 72.27 - Sistemas de  
Inteligencia Artificial - Comisión: S

**Grupo 9**

Pellegrini Jorge Orlando

## Conjunto de datos

7 Atributos

GDP	Luxembourg
Life_expect	Switzerland
Pop_growth	Norway
Area	Netherlands
Military	Ireland
Unemployment	Iceland
Inflation	Austria
	Denmark
	Sweden
	Italy
	Belgium
	Germany
	United Kingdom
	Finland

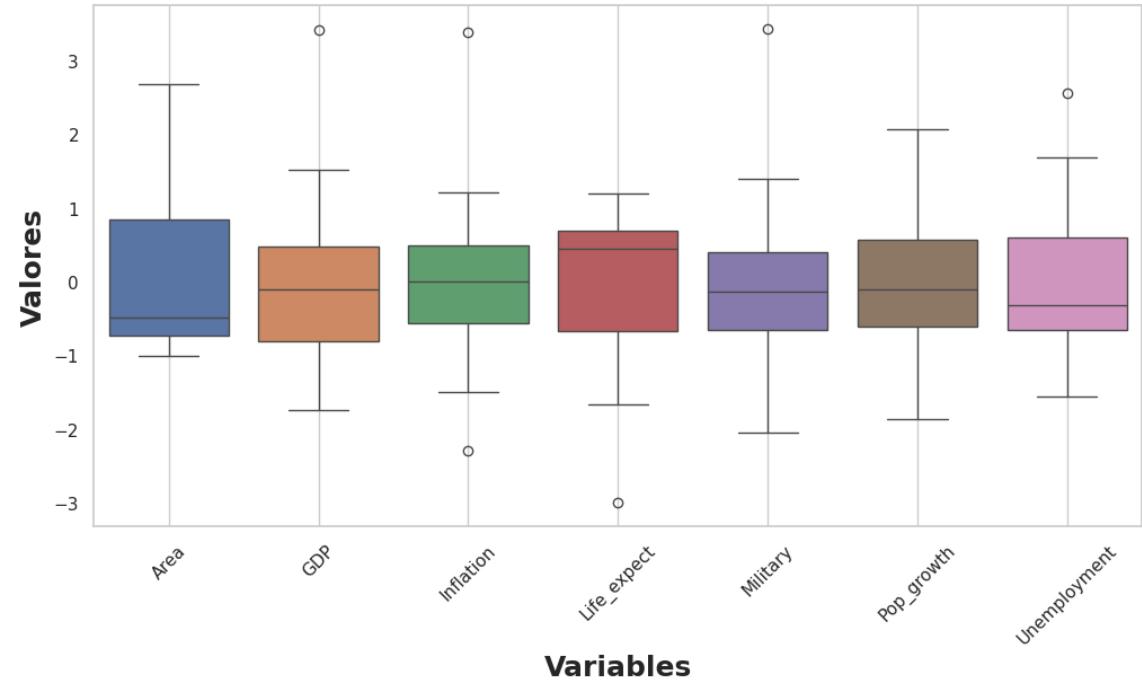
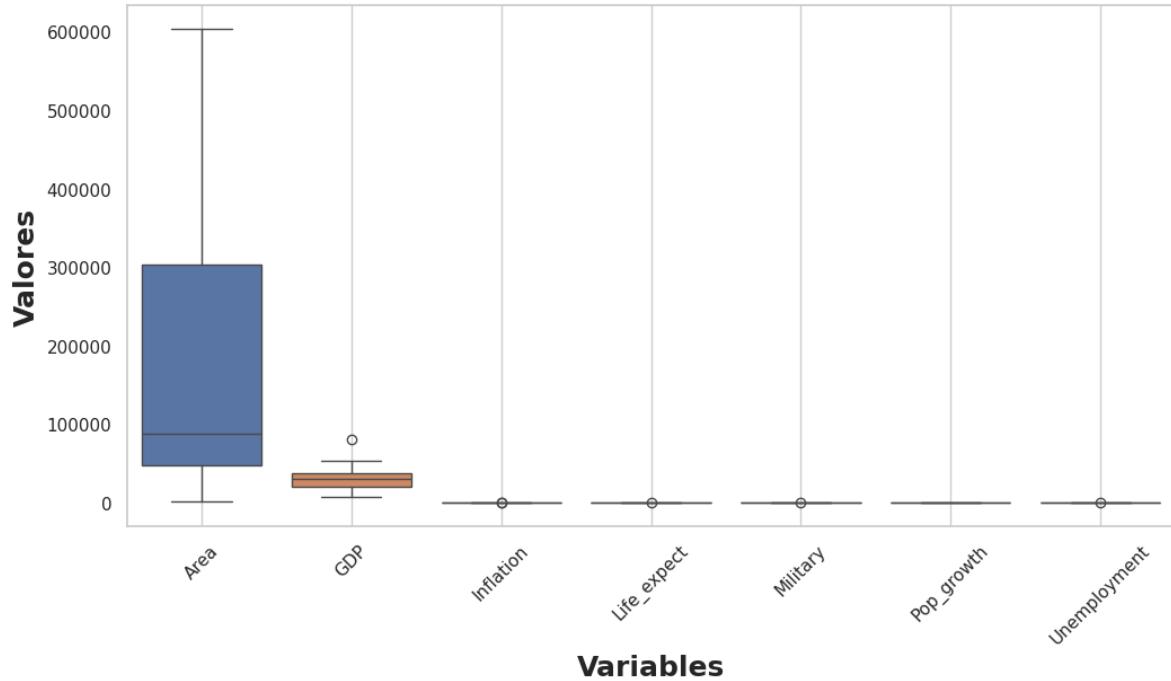
28 Datos

Czech Republic
Spain
Slovenia
Portugal
Slovakia
Greece
Croatia
Hungary
Poland
Lithuania
Latvia
Estonia
Bulgaria
Ukraine

Una regla común es tener al menos 10 instancias de datos por cada atributo.

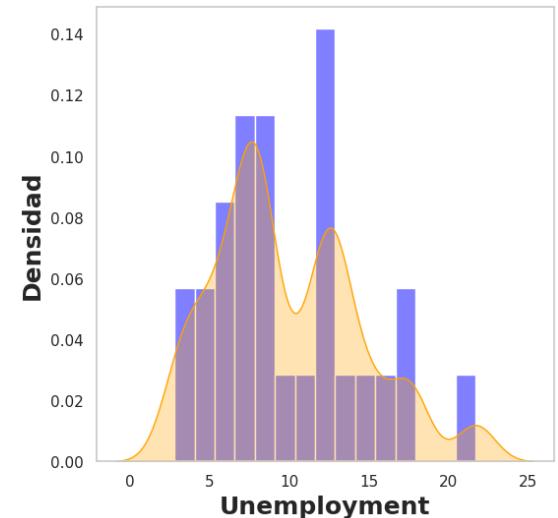
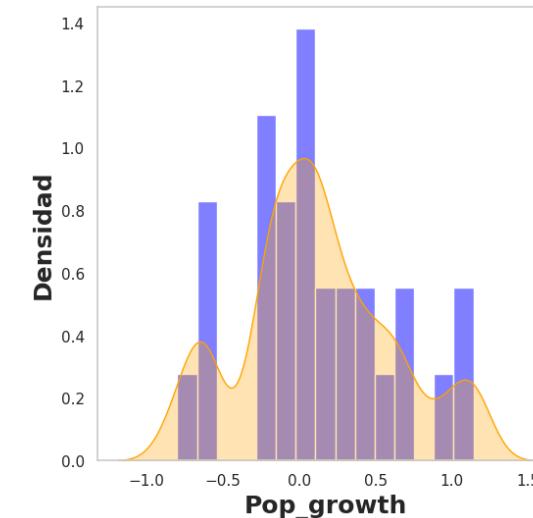
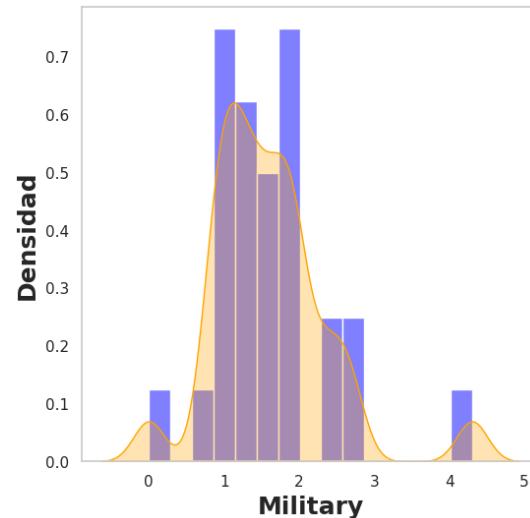
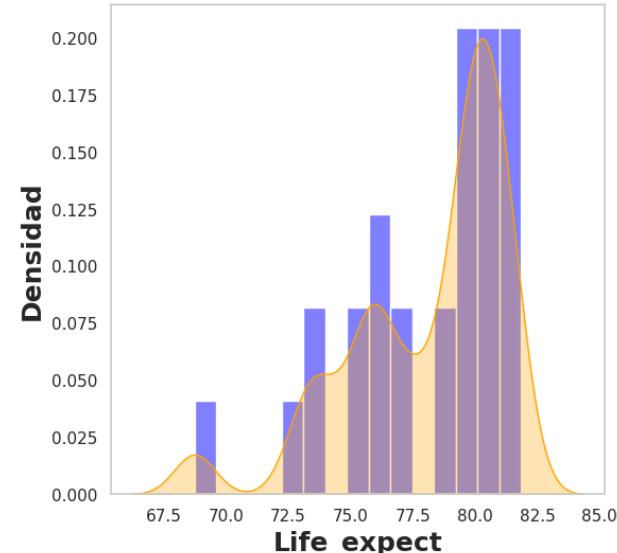
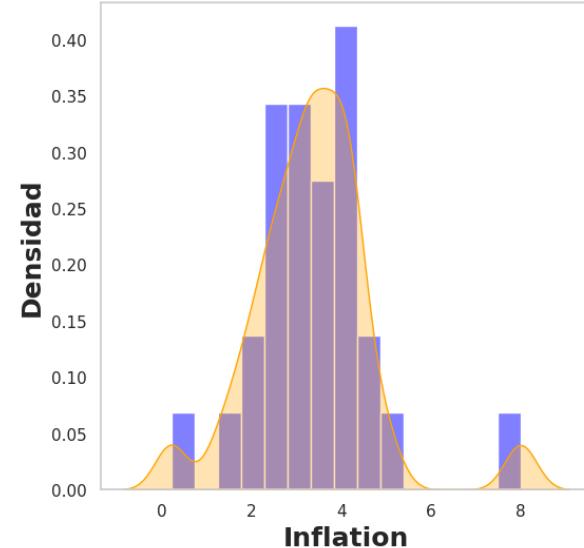
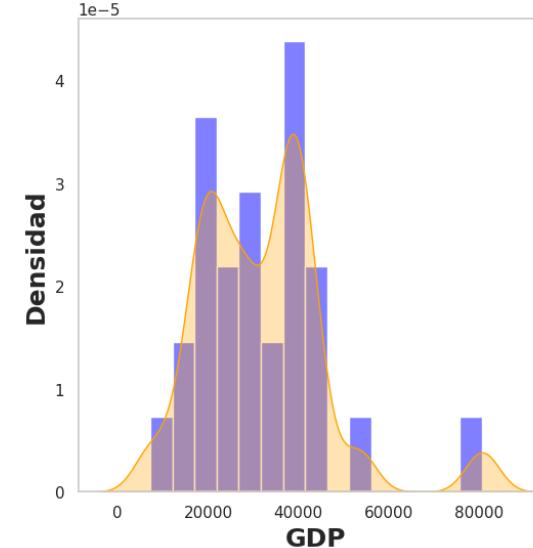
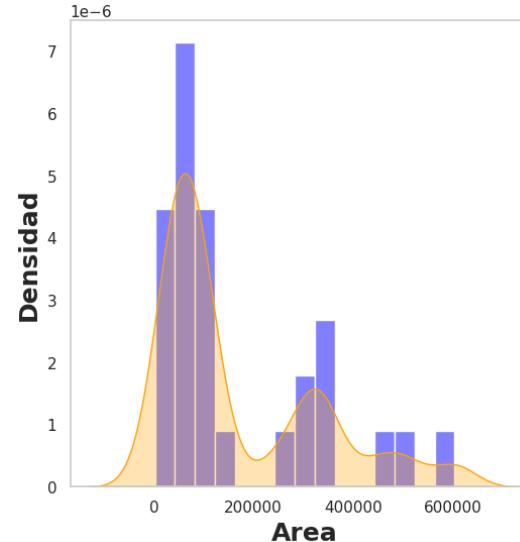
Fuente: Osborne, J. W., & Costello, A. B. (2019). Sample size and subject to item ratio in principal components analysis. Practical Assessment, Research, and Evaluation, 9(1), 11.

## Gráficos de caja

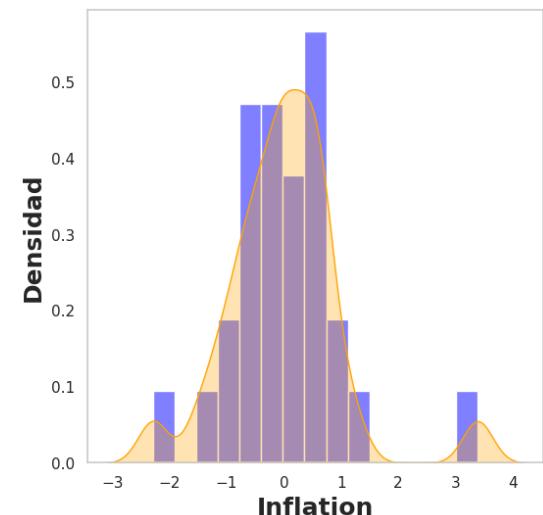
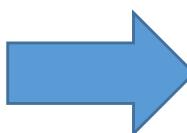
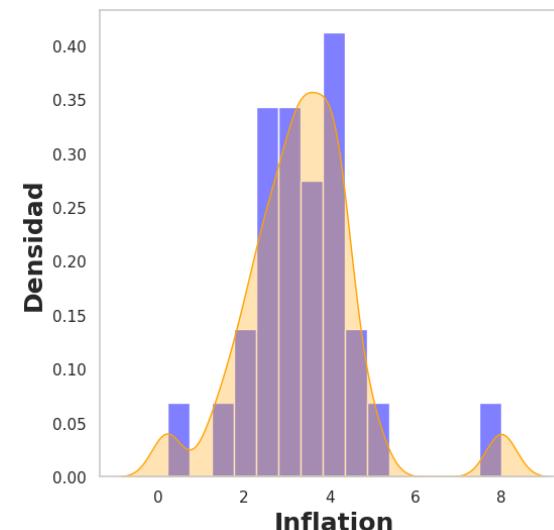
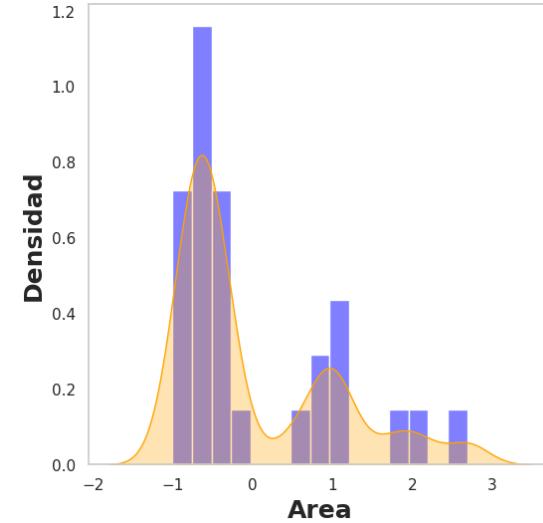
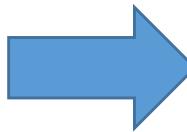
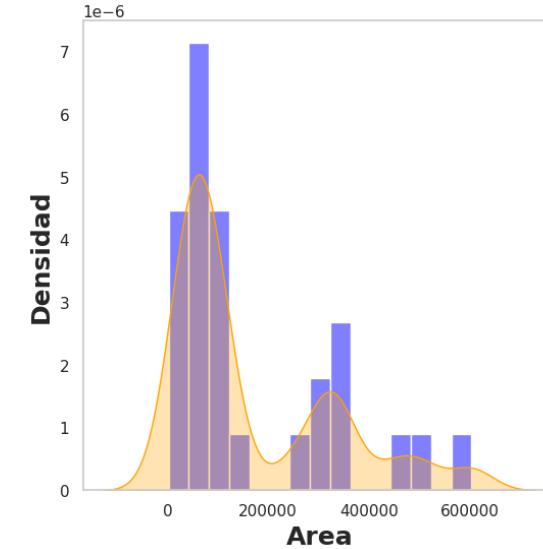


Estandarización est\'andar

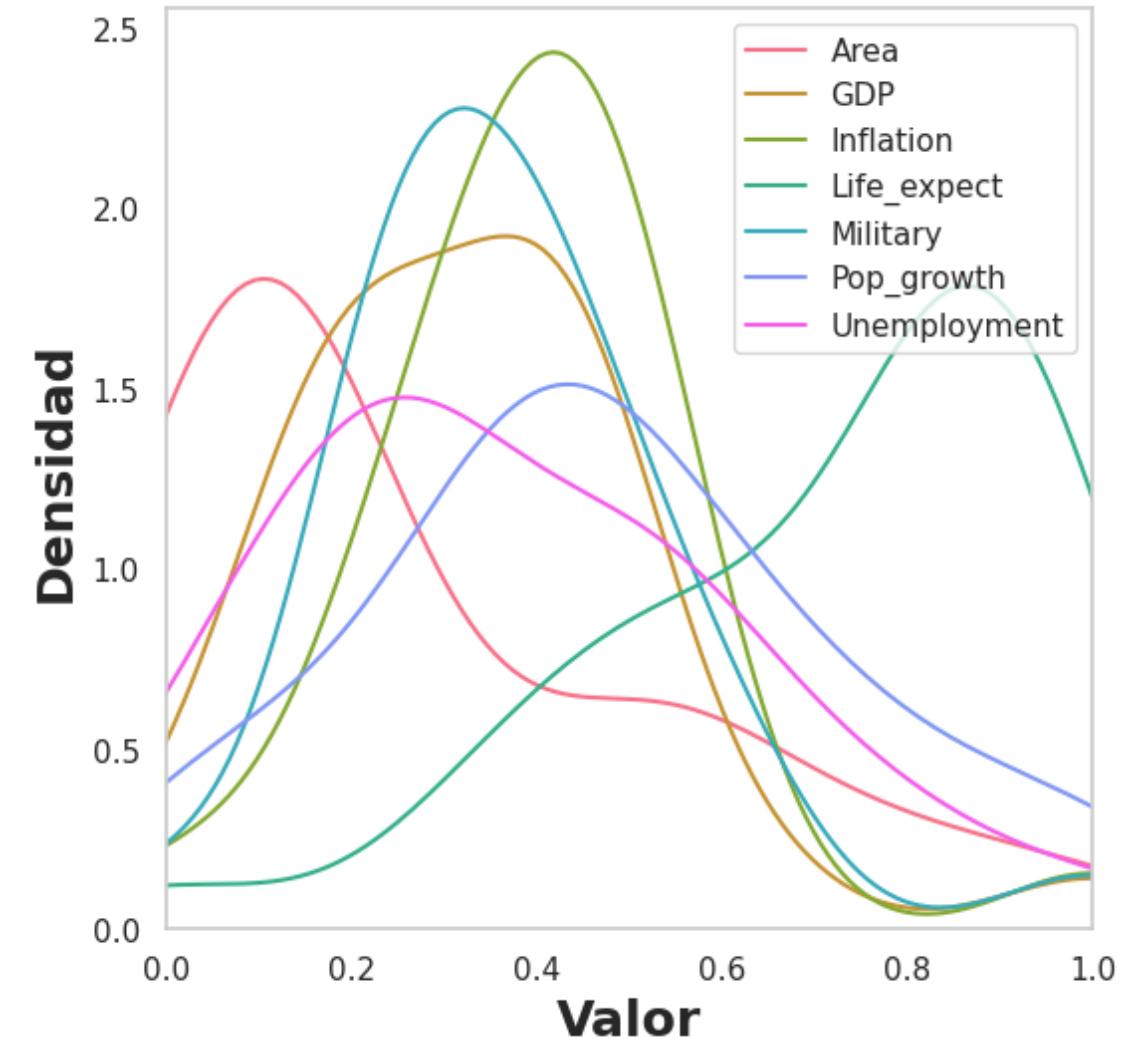
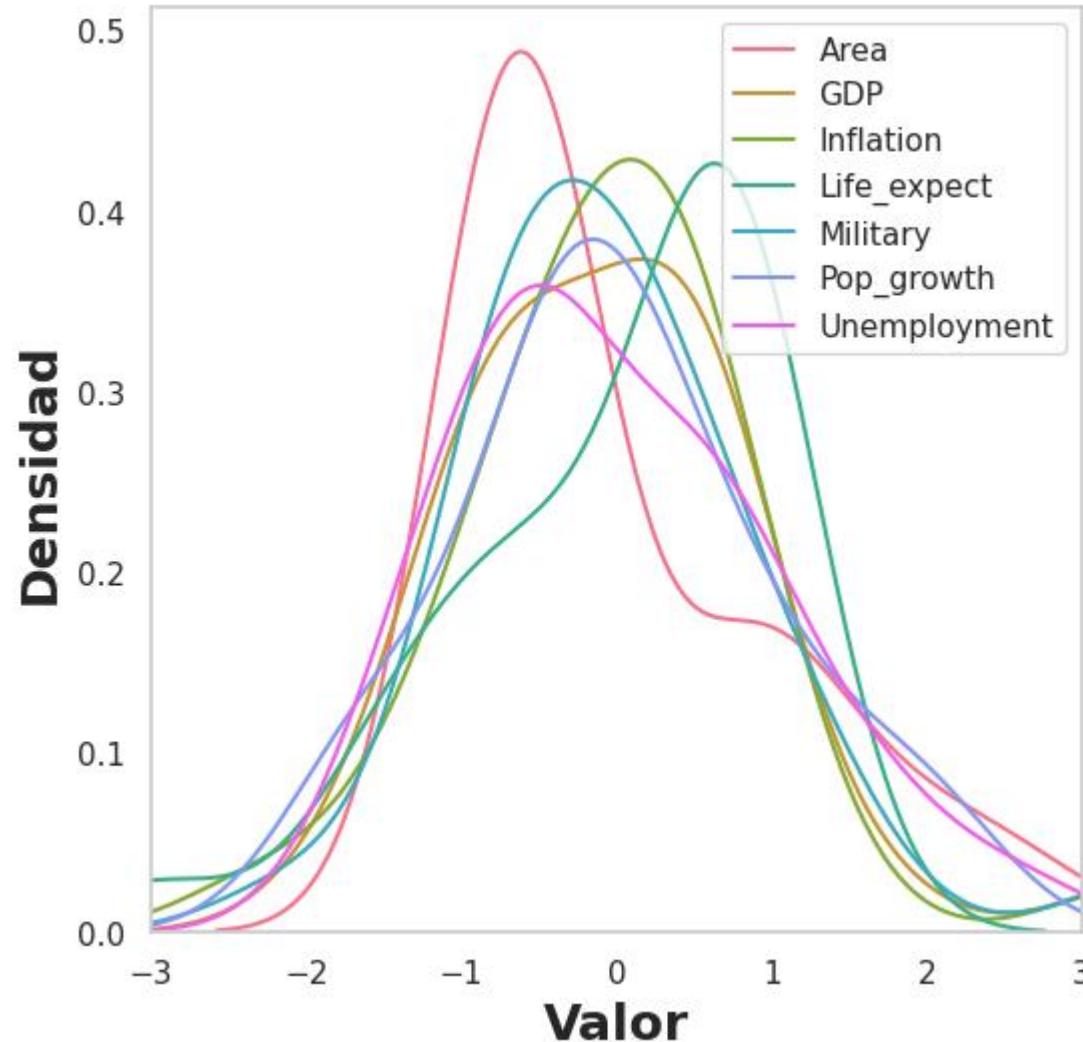
## Histogramas y Estimación de Densidad de Kernel



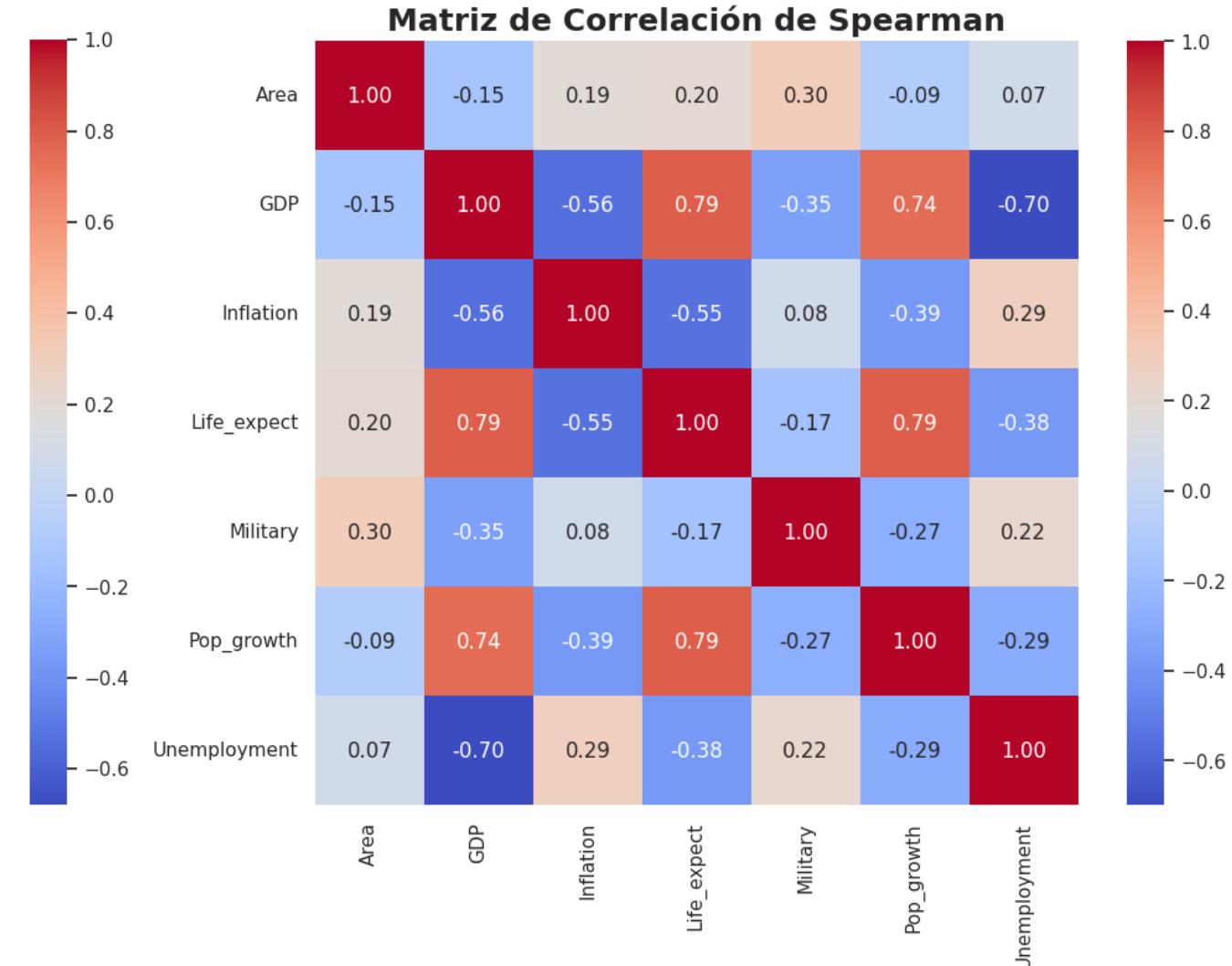
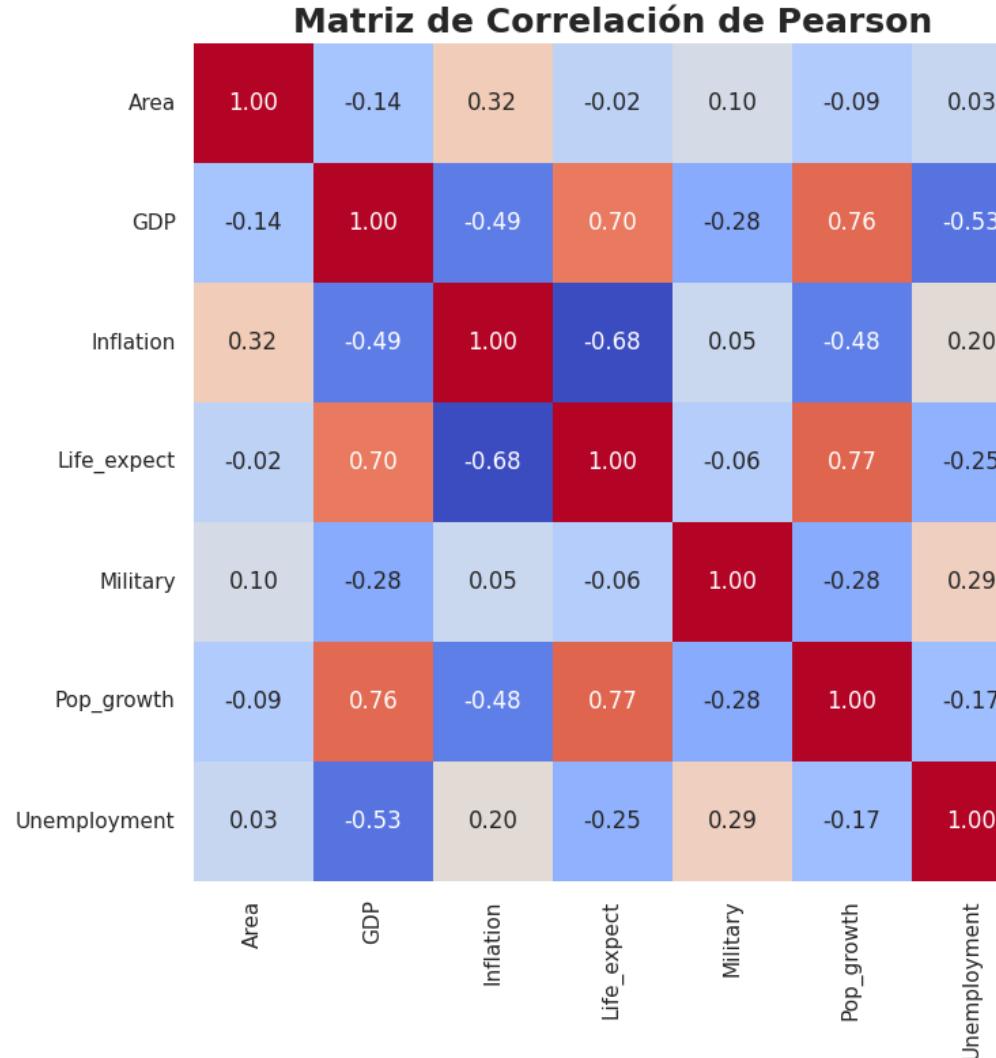
## Estandarización estándar



## Estandarización estándar y MinMax



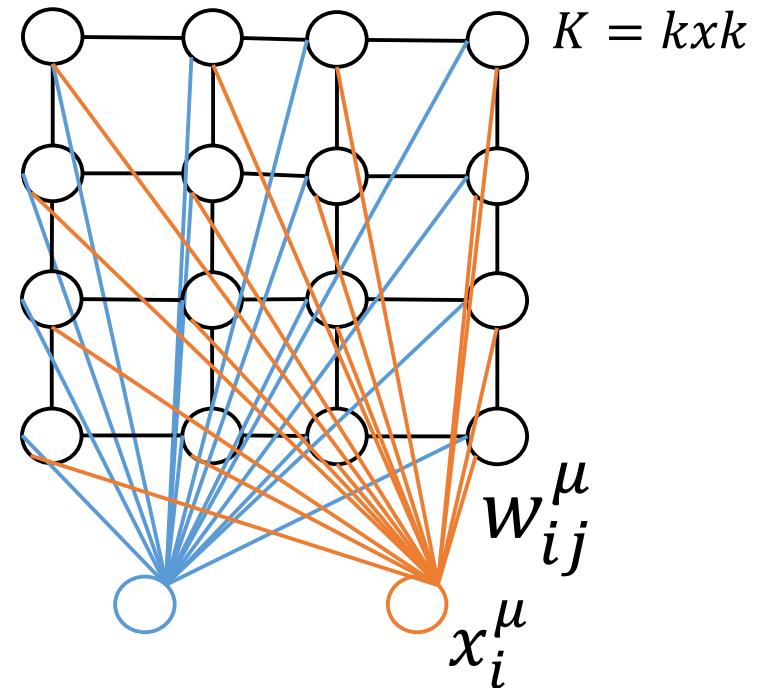
## Matrices de correlación



## Ejercicio 1.1

### Red de Kohonen

Topología Rectangular



## Red de Kohonen

$$\text{Neurona ganadora} = \min |x_i^\mu - w_{ij}| = \min \left( \sqrt{(x_i^\mu - w_{ij})^2} \right)$$

$$w_{ij\,nuevo}^\mu = w_{ij\,viejo}^\mu + \eta \Lambda (x_i^\mu - w_{ij\,viejo}^\mu)$$

$$\Lambda = e^{-\frac{dist([i,j]-[i,j]_{ganadora})}{2\sigma^2}}$$

$$\sigma = \sigma_0 e^{(-\frac{iter}{iter\,max}\beta)}$$

$$K = 5\sqrt{n}$$

Vesanto, J., Himberg, J., Alhoniemi, E., & Parhankangas, J. (1999, November). Self-organizing map in Matlab: the SOM Toolbox. In Proceedings of the Matlab DSP conference (Vol. 99, pp. 16-17).

$\sigma_0$  = Vecindad inicial

$W_{inicial}$  = Distribución uniforme (0; 1)

$\eta$  = tasa de aprendizaje

## Resultados

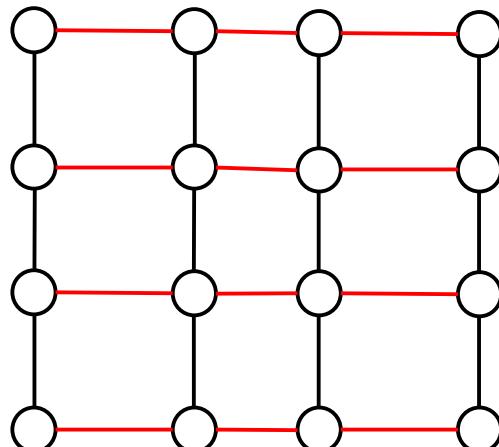
$Red = 5 \times 5$

$iter\ max = 150$

$\eta = 0.3$

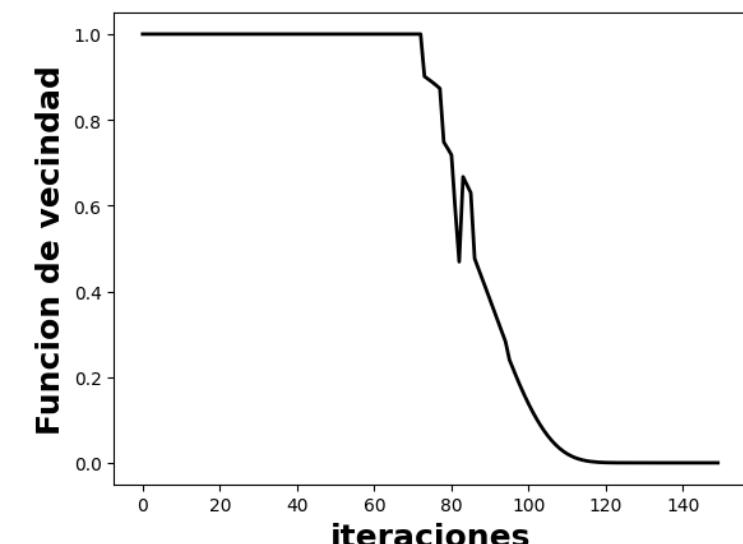
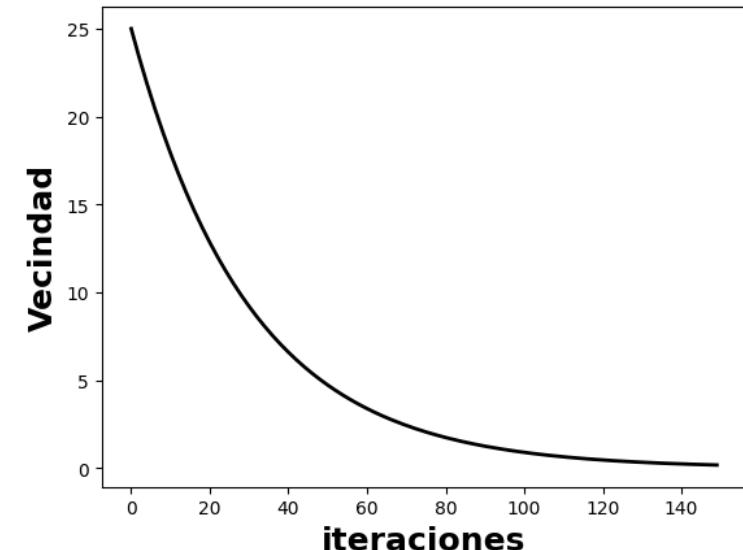
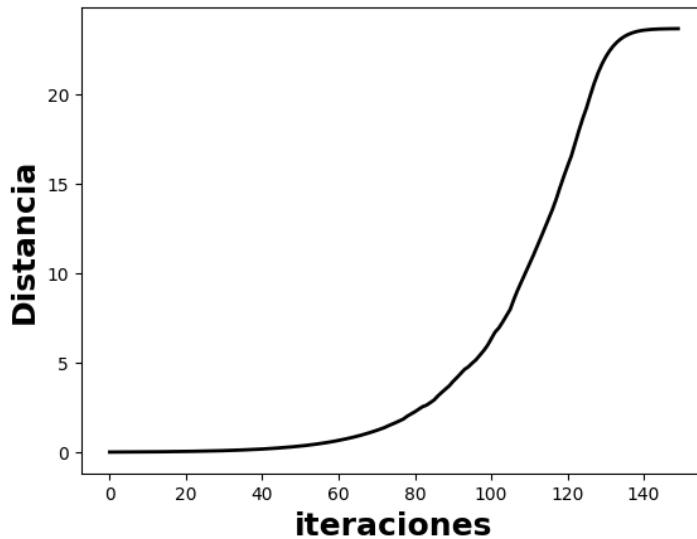
$\sigma_0 = 25$

$\beta = 5$



$$Distancia = \sum dist(w_{ij+1}^{\mu} - w_{ij}^{\mu})$$

Para todos los atributos



Para la ultima neurona y ultimo atributo

## Resultados

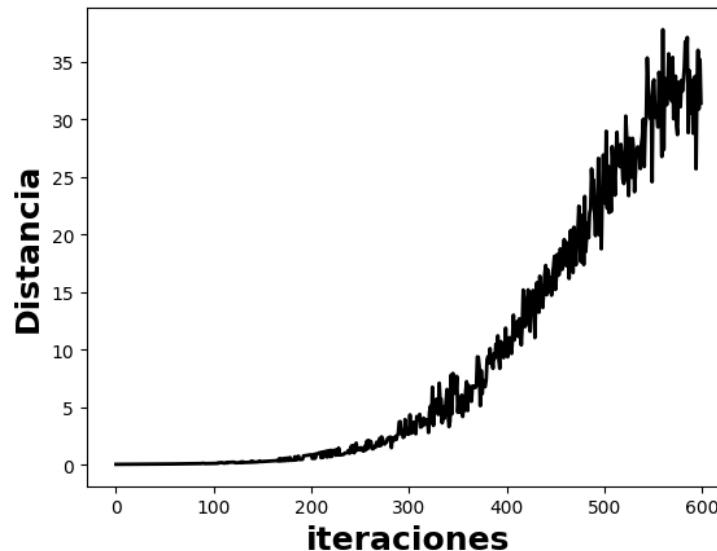
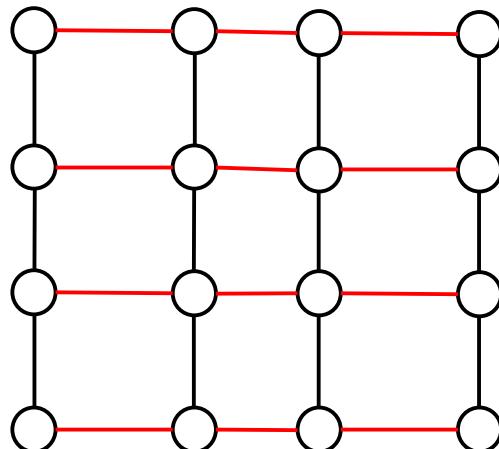
*Red = 5x5*

*iter max = 600*

$\eta = 0.5$

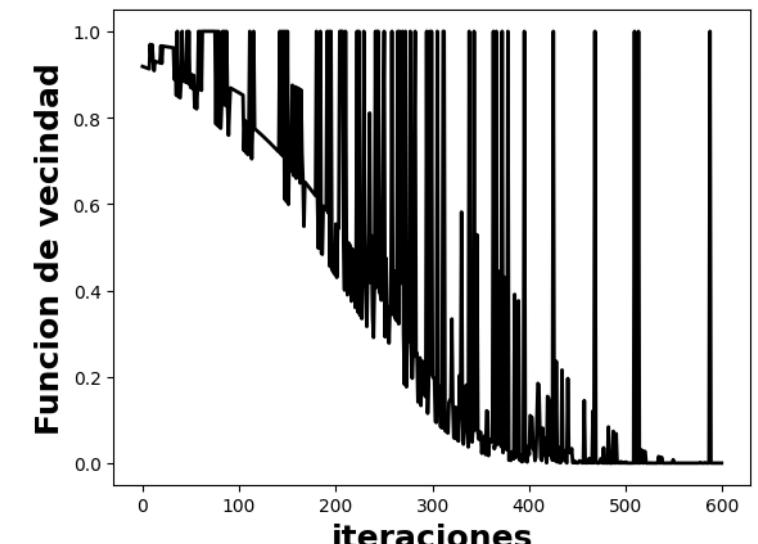
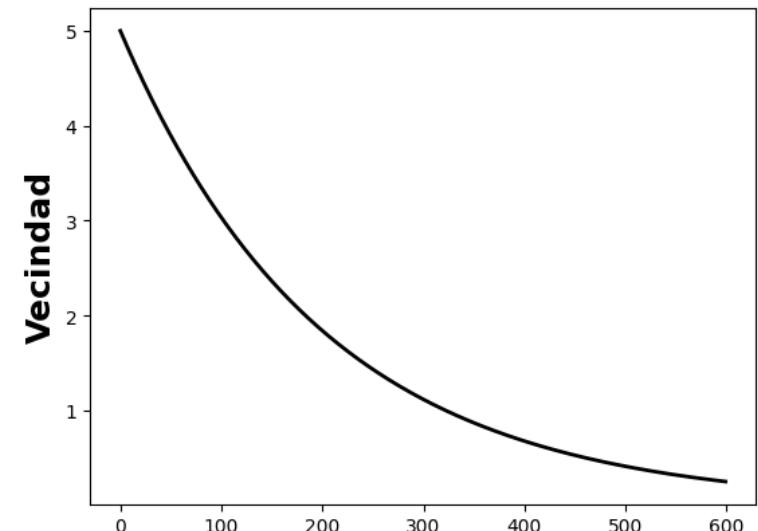
$\sigma_0 = 5$

$\beta = 3$



$$Distancia = \sum dist(w_{ij+1}^{\mu} - w_{ij}^{\mu})$$

Para todos los atributos



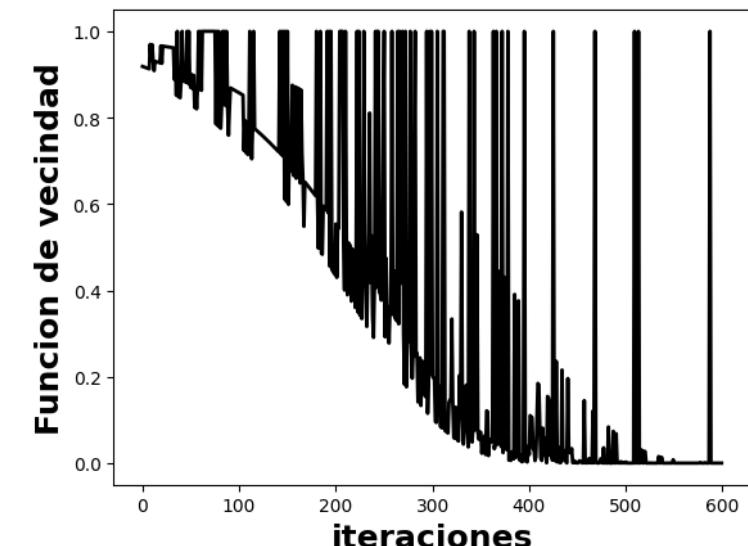
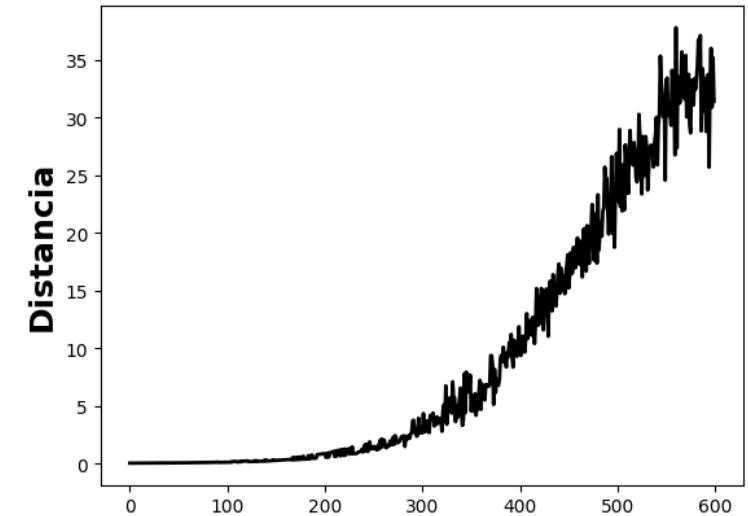
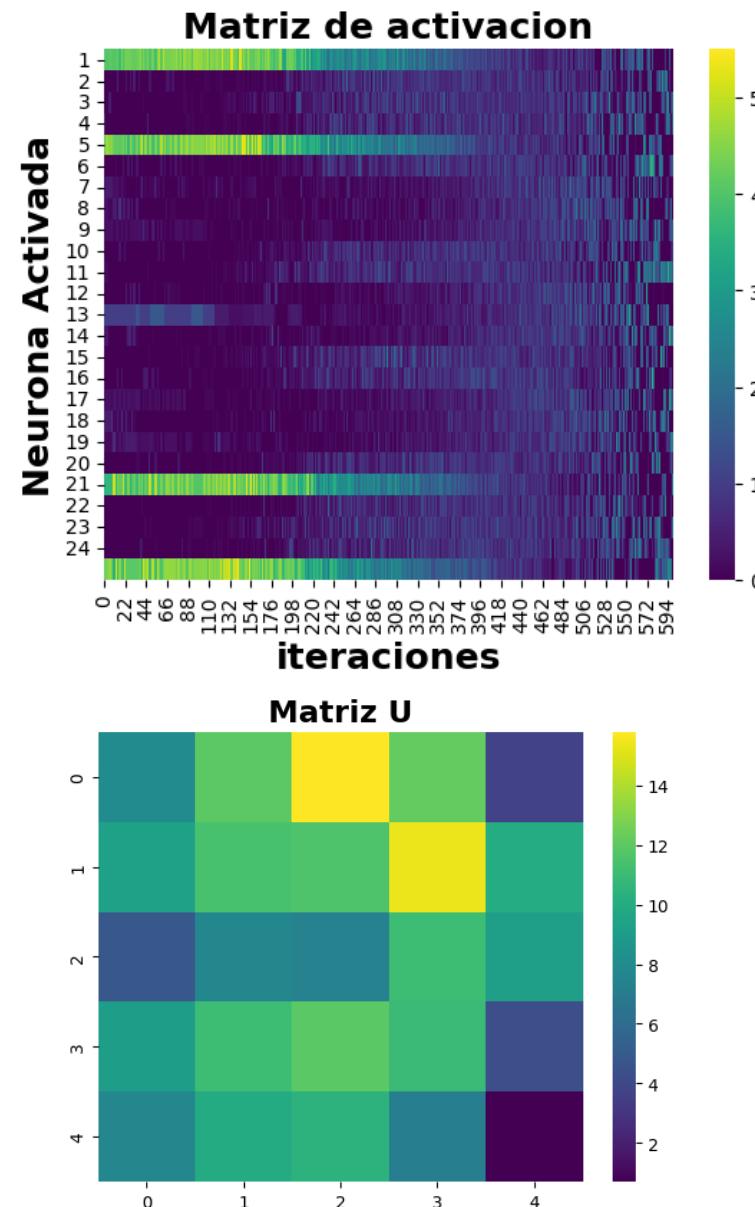
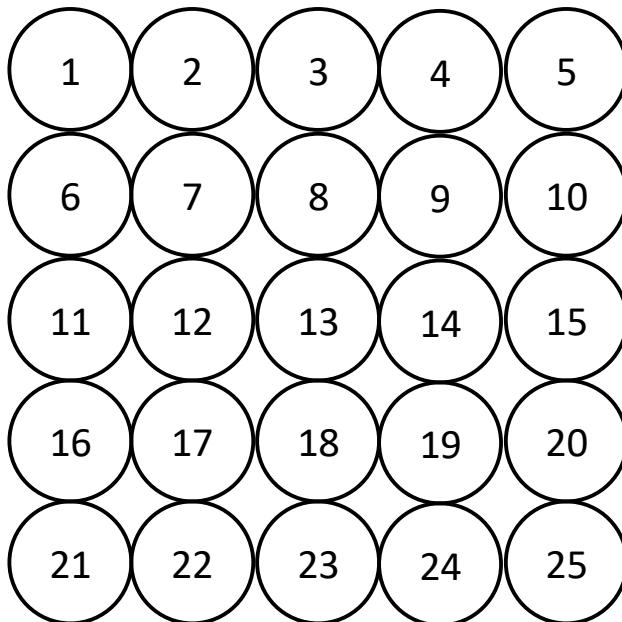
Para la ultima neurona y ultimo atributo

# Resultados

$W_{inicial} = \text{Distribución uniforme } (0; 1)$

$iter\ max = 600$        $\sigma_0 = 5$

$\eta = 0.5$        $\beta = 3$



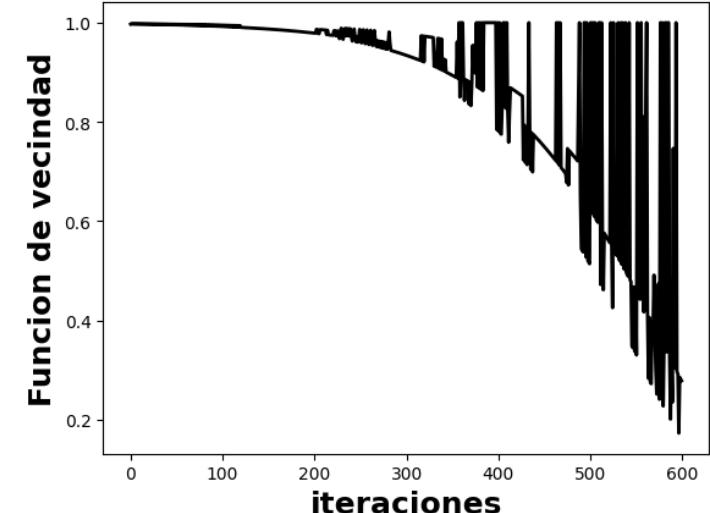
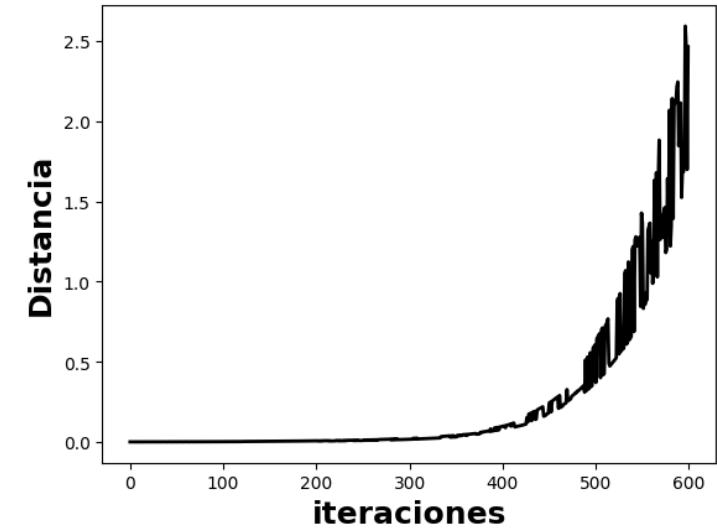
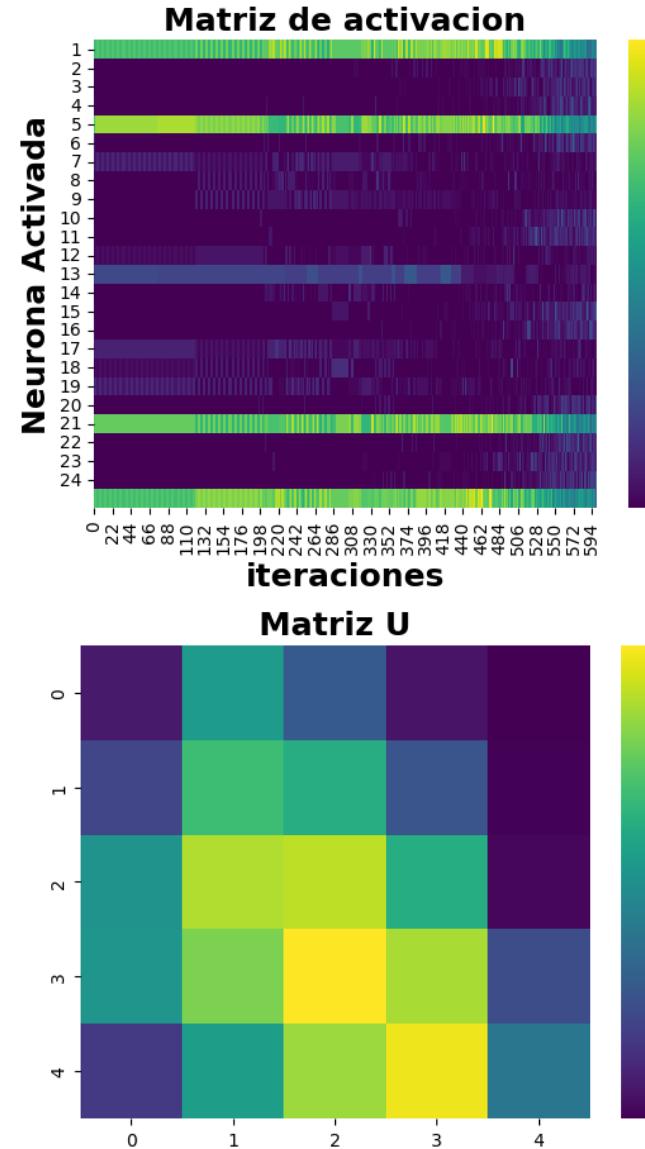
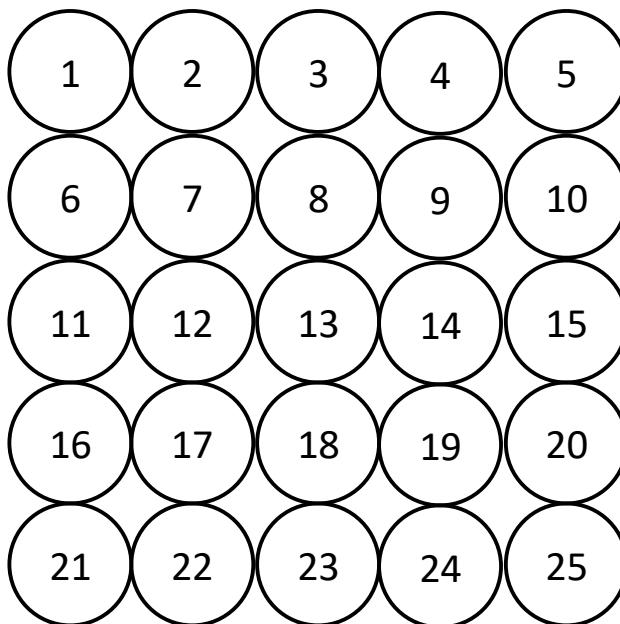
Para la ultima neurona y ultimo atributo

## Resultados

$W_{inicial} = \text{Distribución uniforme } (0; 1)$

$iter\ max = 600$        $\sigma_0 = 25$

$\eta = 0.5$        $\beta = 3$



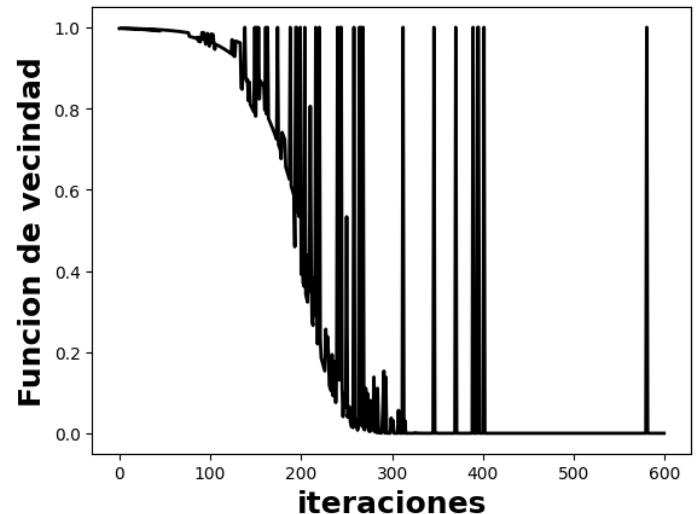
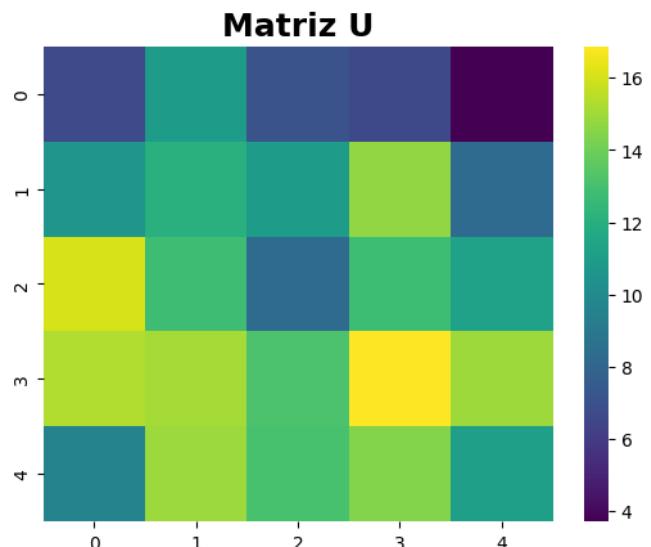
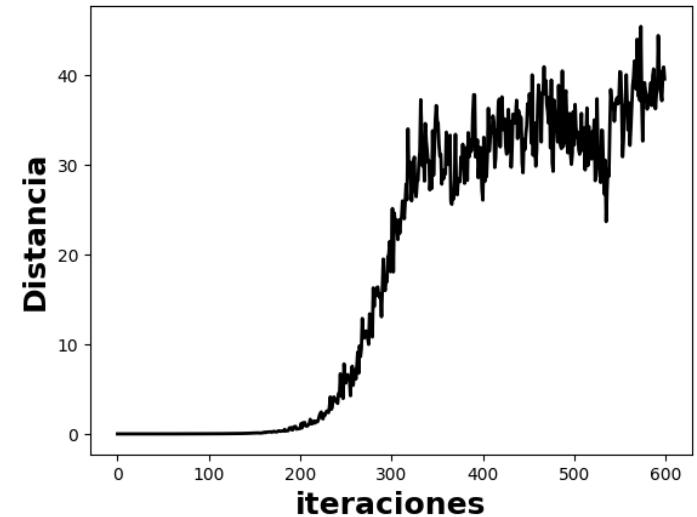
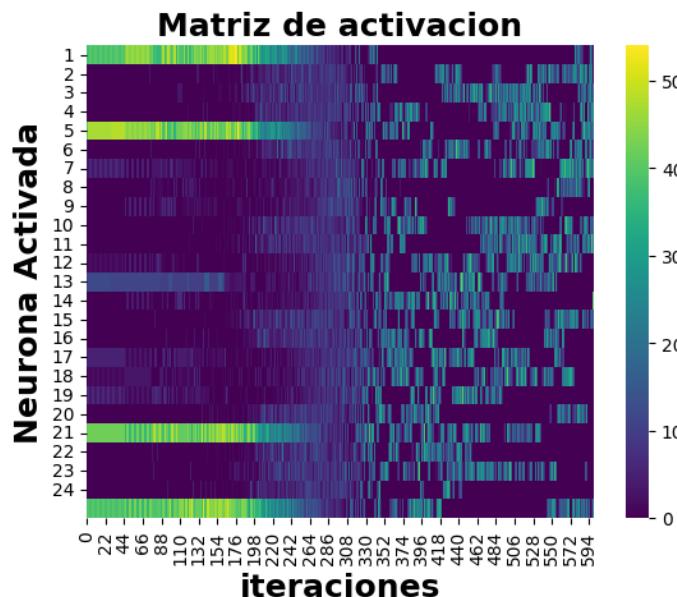
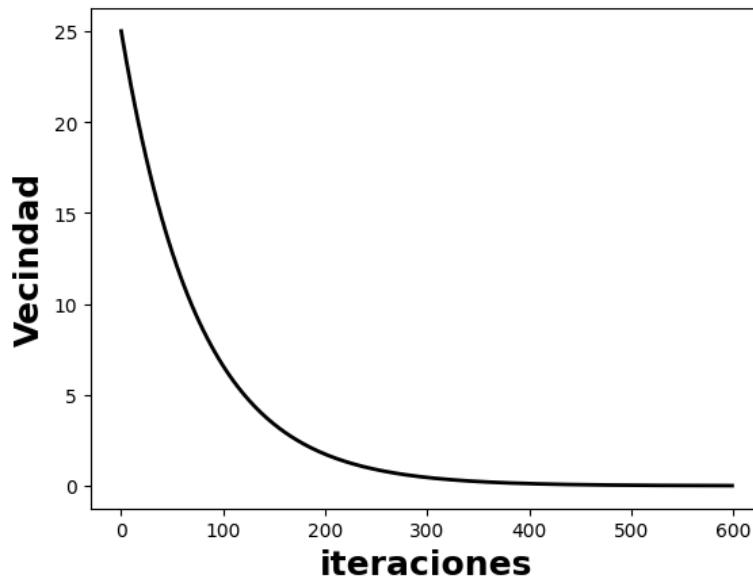
Para la ultima neurona y ultimo atributo

# Resultados

$W_{inicial} = \text{Distribución uniforme } (0; 1)$

$iter\ max = 600$        $\sigma_0 = 25$

$\eta = 0.5$        $\beta = 8$



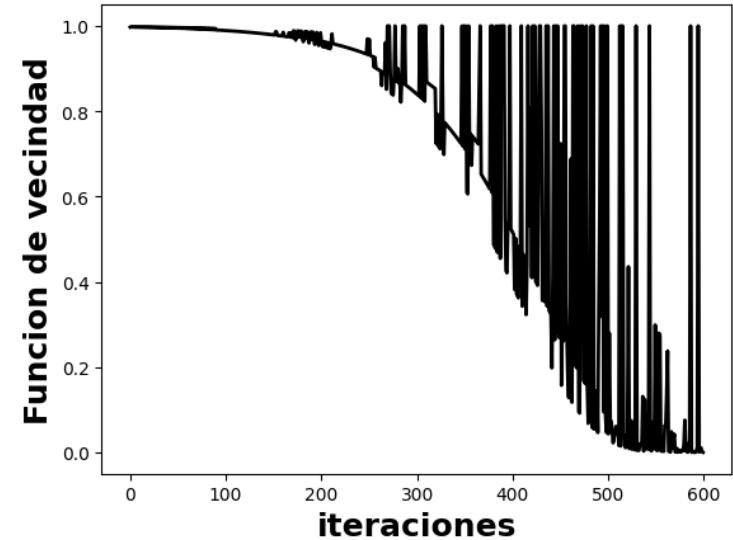
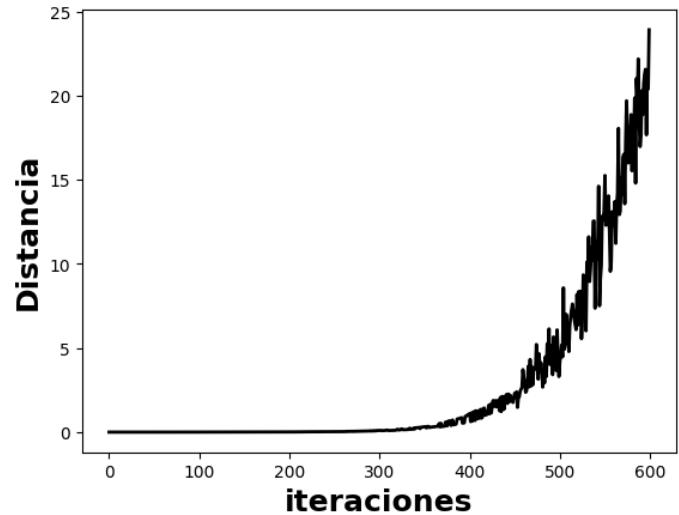
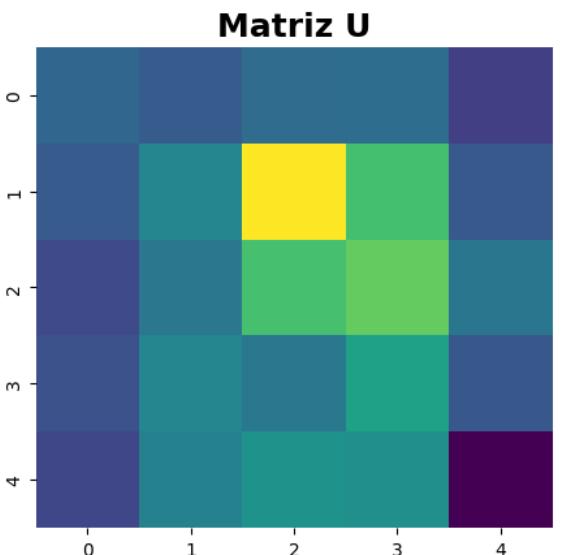
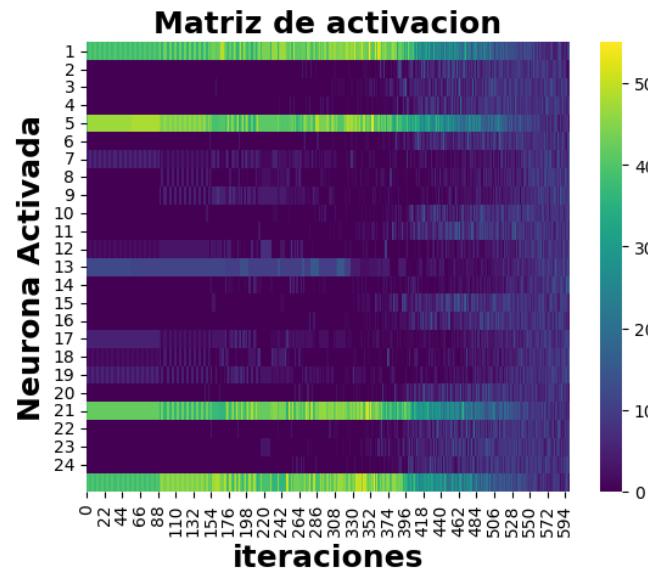
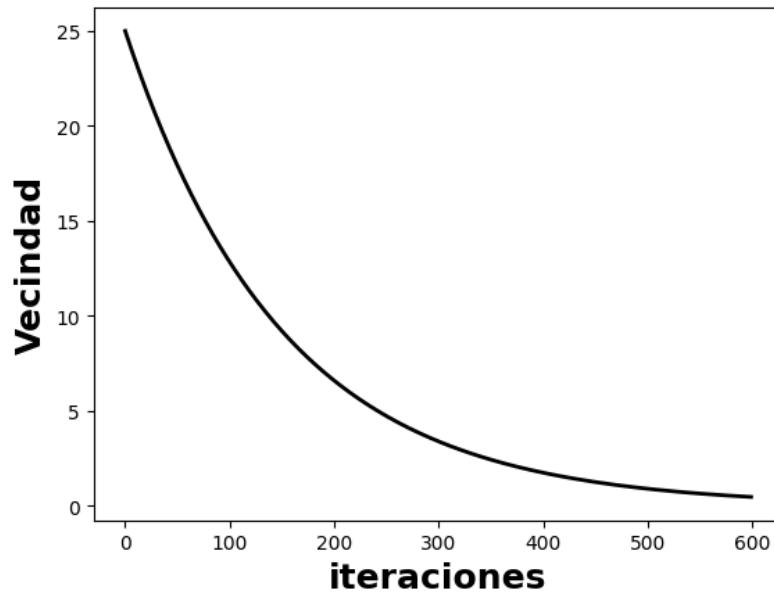
Para la ultima neurona y ultimo atributo

# Resultados

$W_{inicial} = \text{Distribución uniforme } (0; 1)$

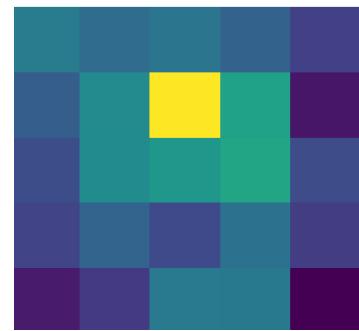
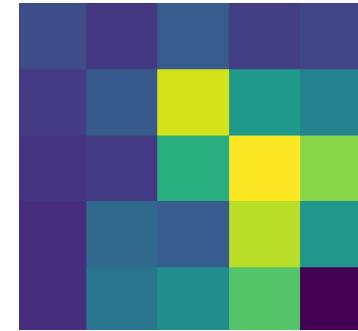
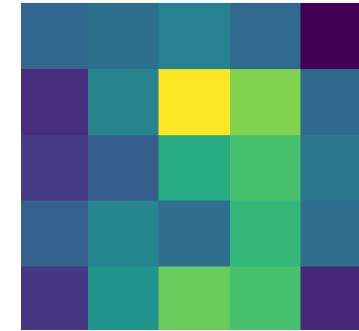
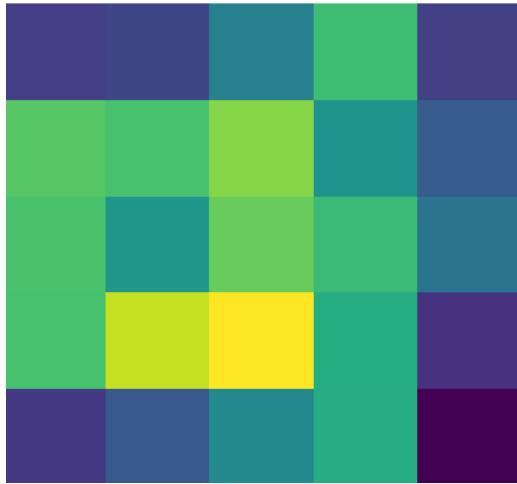
$iter\ max = 600$        $\sigma_0 = 25$

$\eta = 0.5$        $\beta = 4$

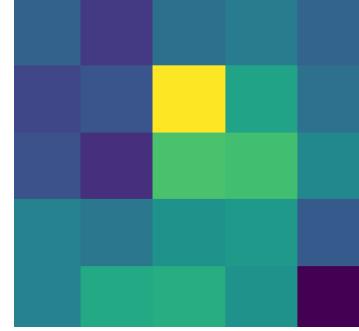
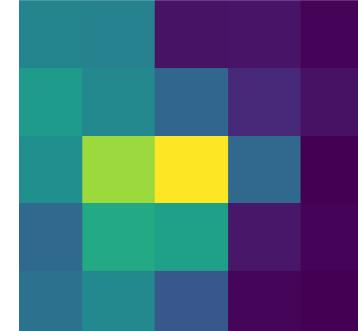
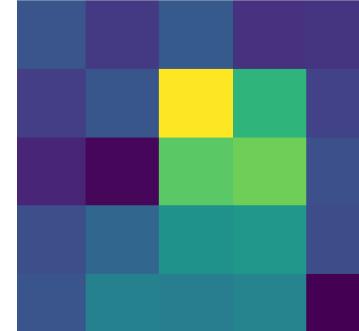
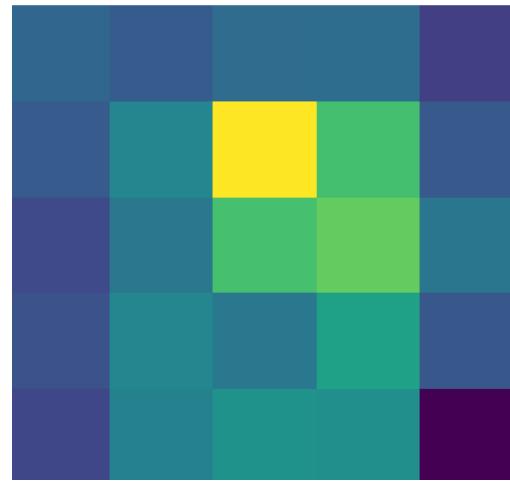


Para la ultima neurona y ultimo atributo

**Matriz U inicial**



**Matriz U**

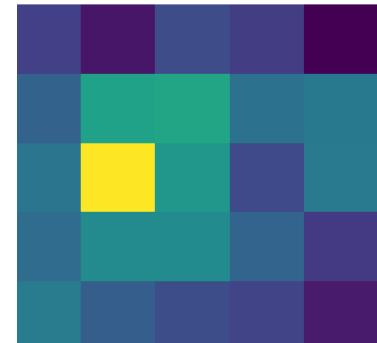
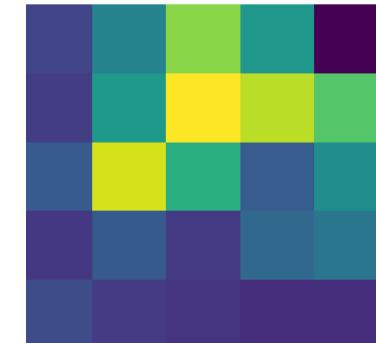
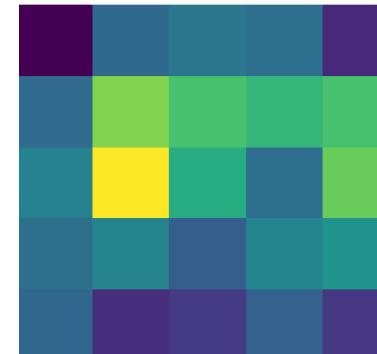
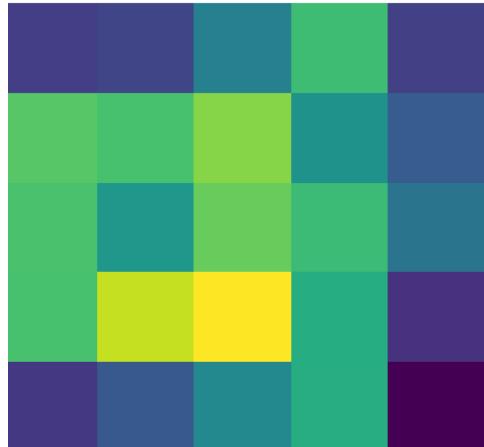


$W_{inicial} = \text{Distribución uniforme } (0; 1)$

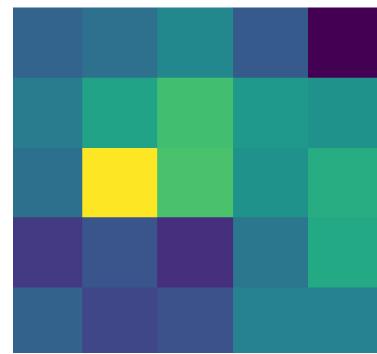
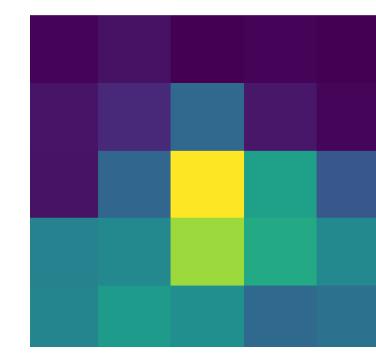
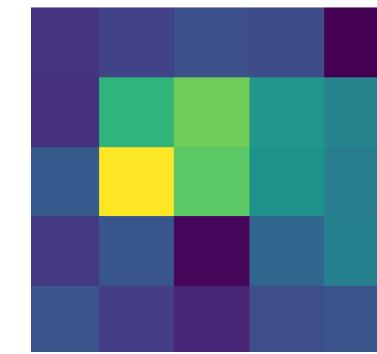
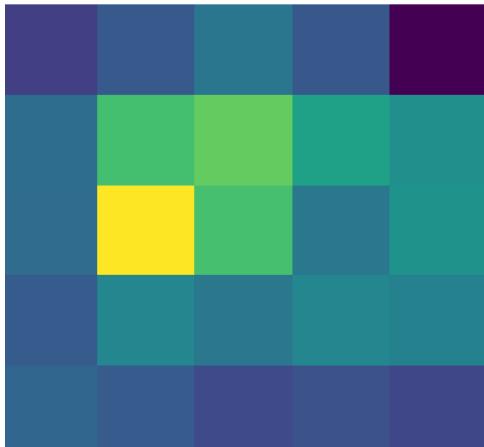
$iter\ max = 600 \quad \sigma_0 = 25$

$\eta = 0.5 \quad \beta = 4$

**Matriz U inicial**



**Matriz U**



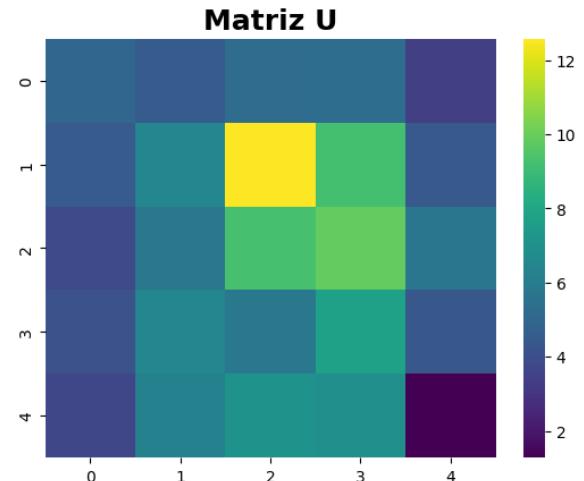
$W_{initial} = \text{Distribución uniforme } (-1; 1)$

$iter\ max = 600 \quad \sigma_0 = 25$

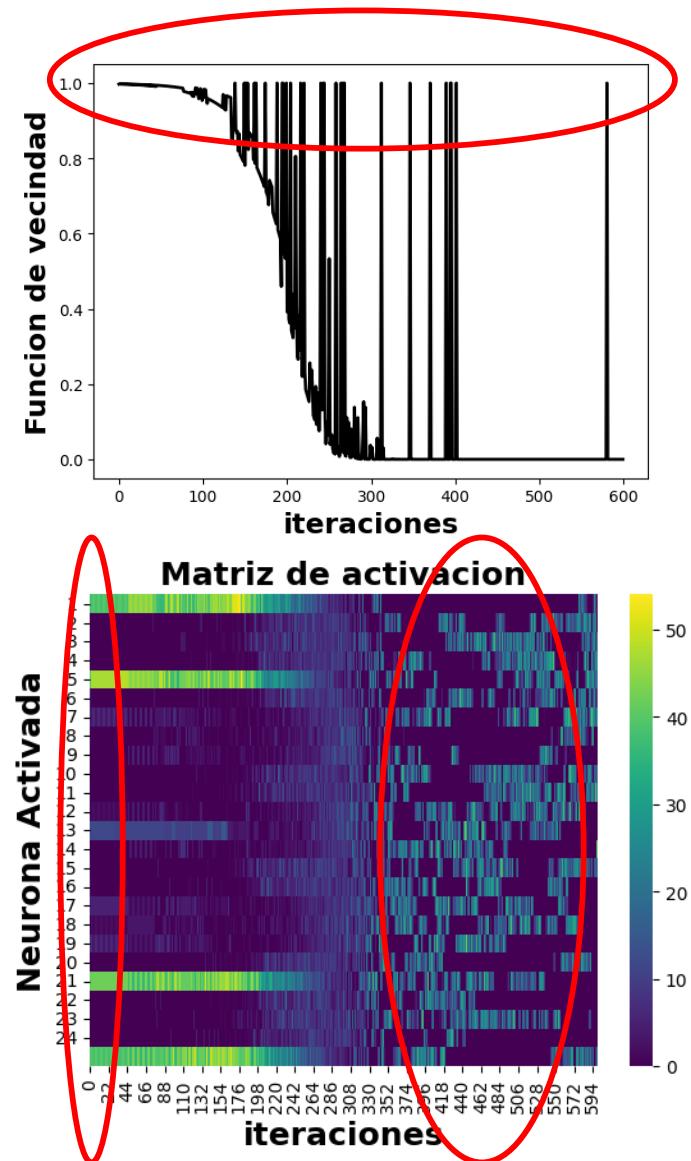
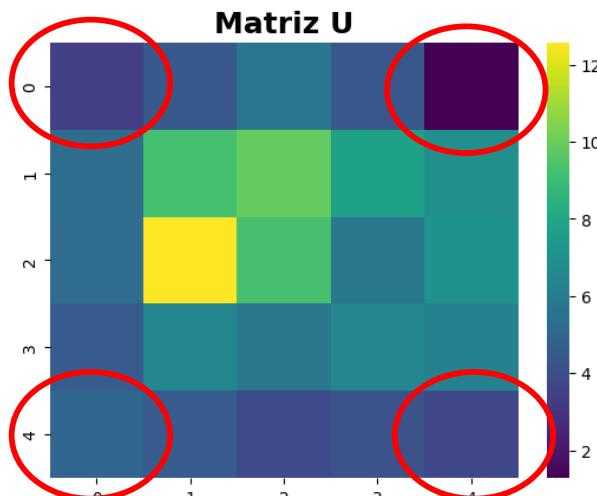
$\eta = 0.5 \quad \beta = 4$

## Problema con el código

$W_{inicial} = \text{Dist uniforme } (0; 1)$



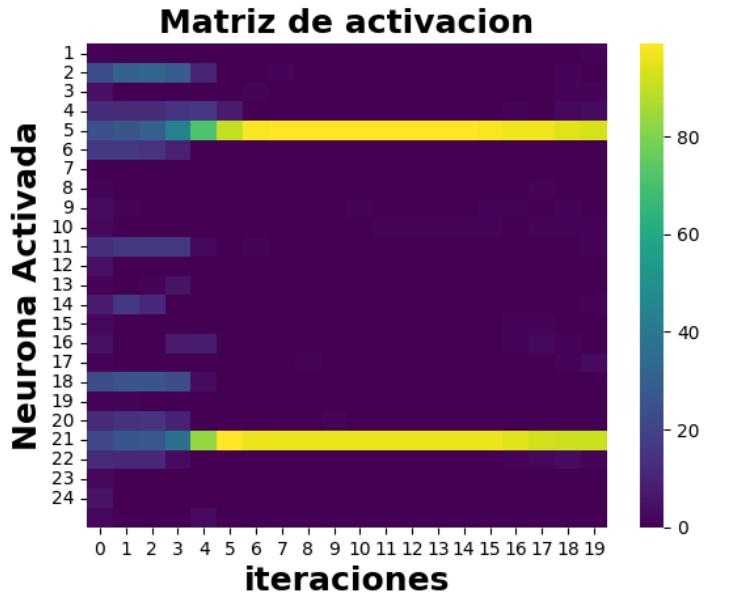
$W_{inicial} = \text{Dist uniforme } (-1; 1)$



## Resultados

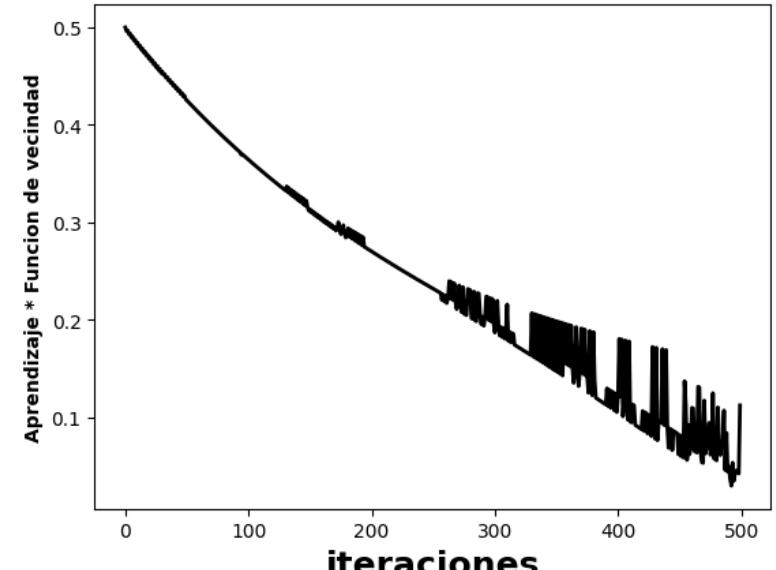
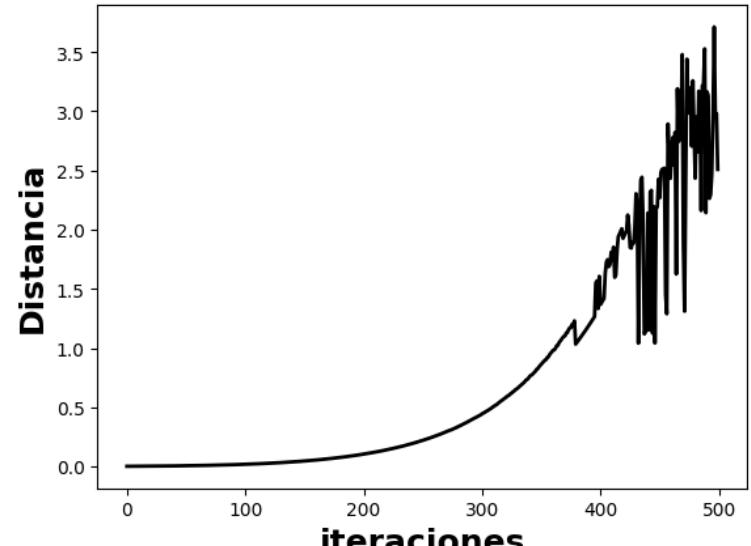
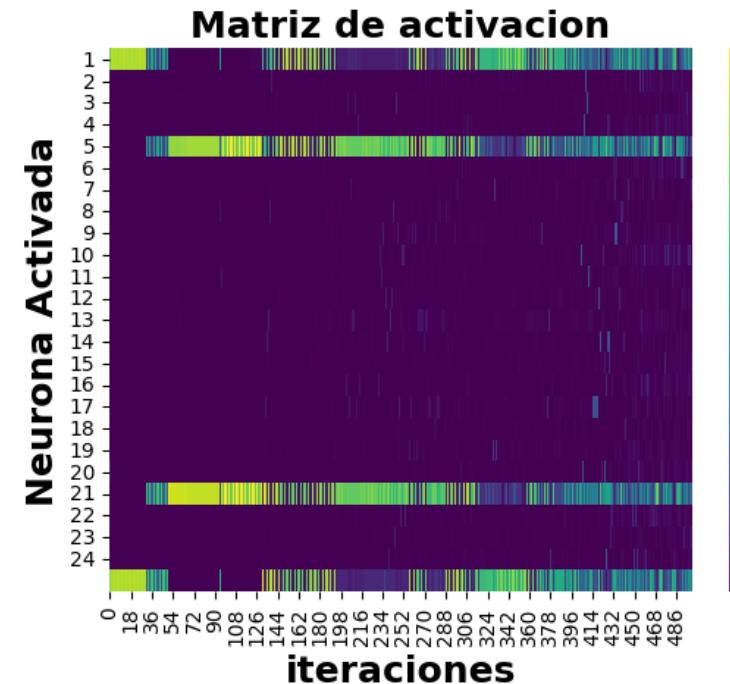
$iter\ max = 20$

$\eta_0 = 0.01$



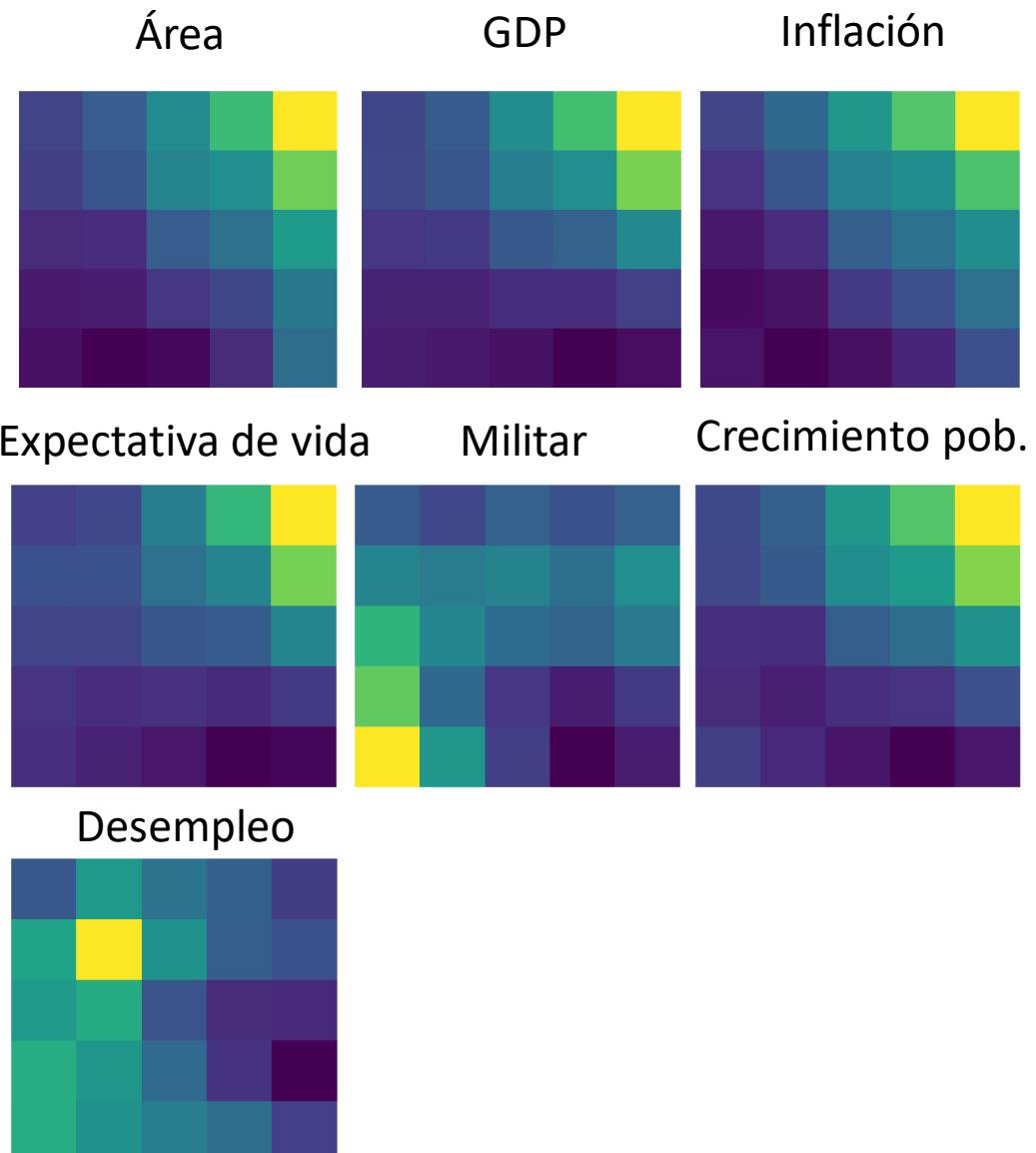
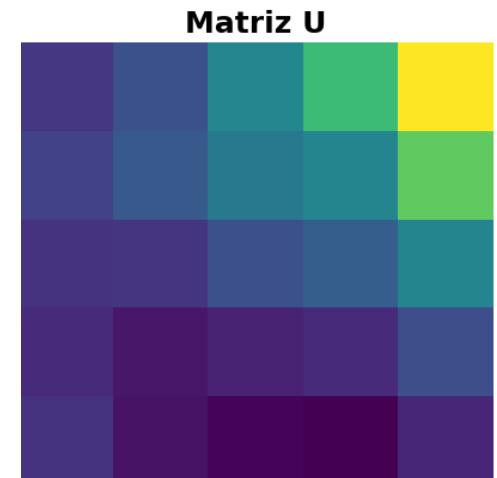
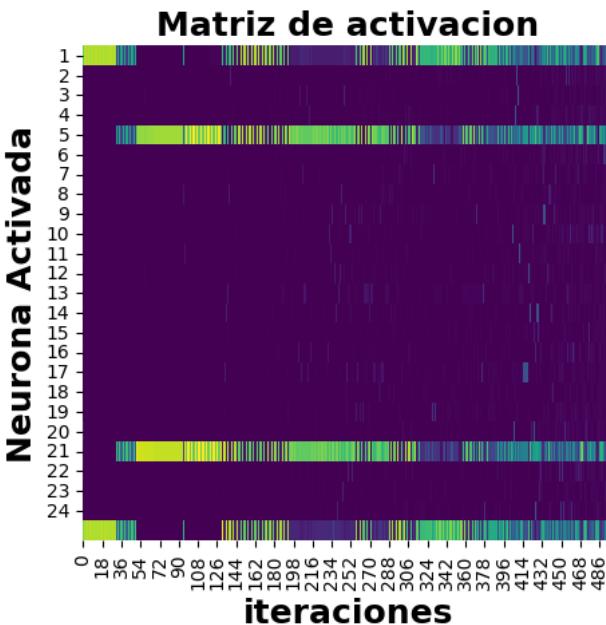
$\sigma_0 = 25$

$\eta_0 = 0.4 \ iter\ max = 500$



Para la ultima neurona y ultimo atributo

## Resultados



# Sistemas de Inteligencia Artificial 2024 2Q

Area				
1	0	0	0	3
1	0	1	1	0
0	0	1	0	0
0	0	0	0	0
0	0	0	0	20

GDP				
2	0	0	0	10
0	0	1	1	1
0	0	0	0	0
0	0	0	0	0
13	0	0	0	0

Inflation				
0	2	0	1	1
0	0	0	0	0
18	0	0	1	1
0	2	1	1	0
0	0	0	0	0

Life_expect				
0	0	0	1	5
0	0	0	0	3
0	0	0	1	1
0	0	0	0	0
15	0	2	0	0

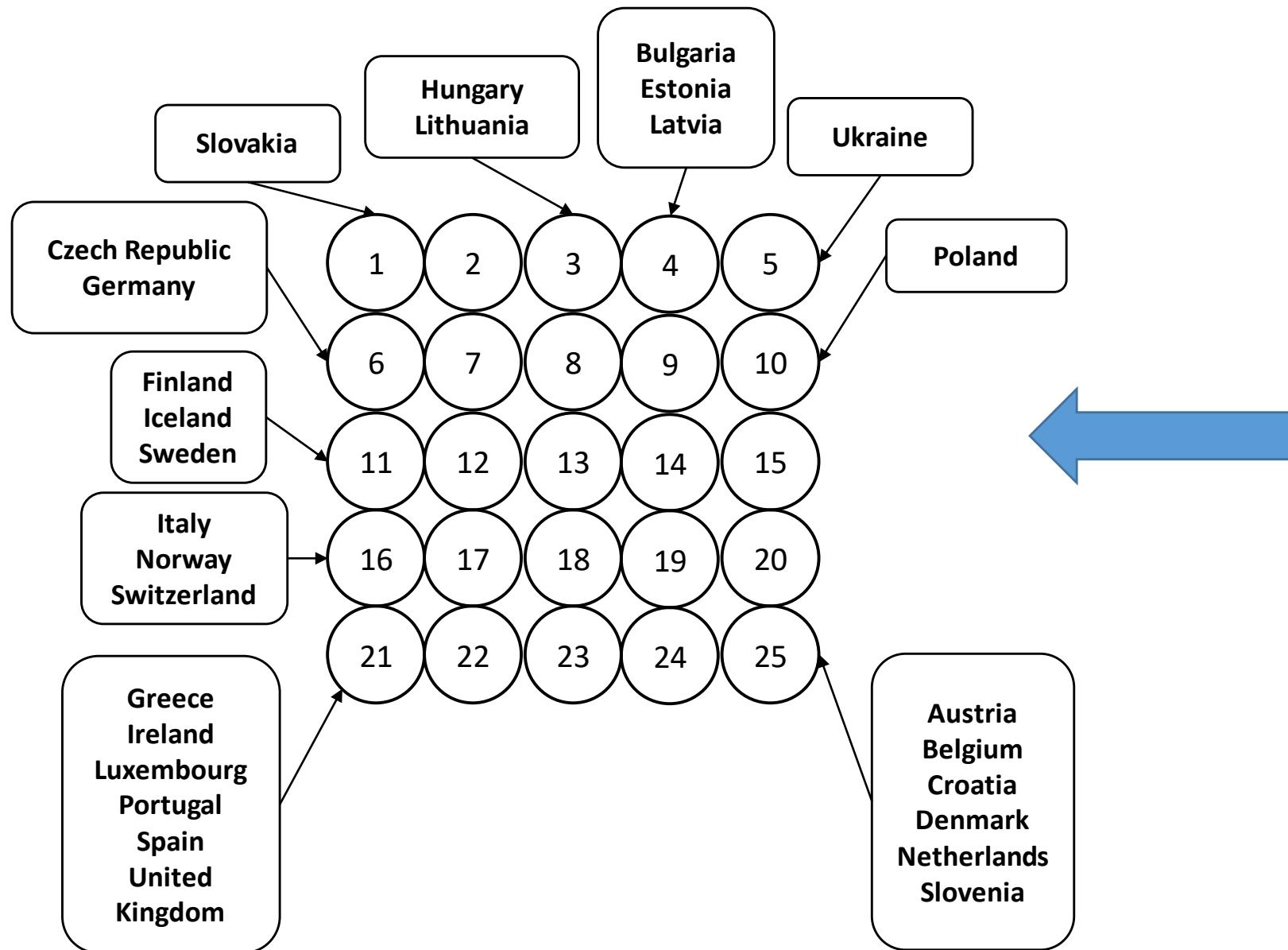
Military				
16	0	0	0	0
1	0	1	0	1
0	0	0	0	2
0	0	0	0	0
5	2	0	0	0

Pop_growth				
0	0	2	4	11
0	0	0	0	1
0	0	0	1	0
1	0	1	0	0
7	0	0	0	0

Unemployment				
0	0	0	0	0
0	10	1	0	0
0	0	1	0	0
1	0	0	0	1
13	0	1	0	0

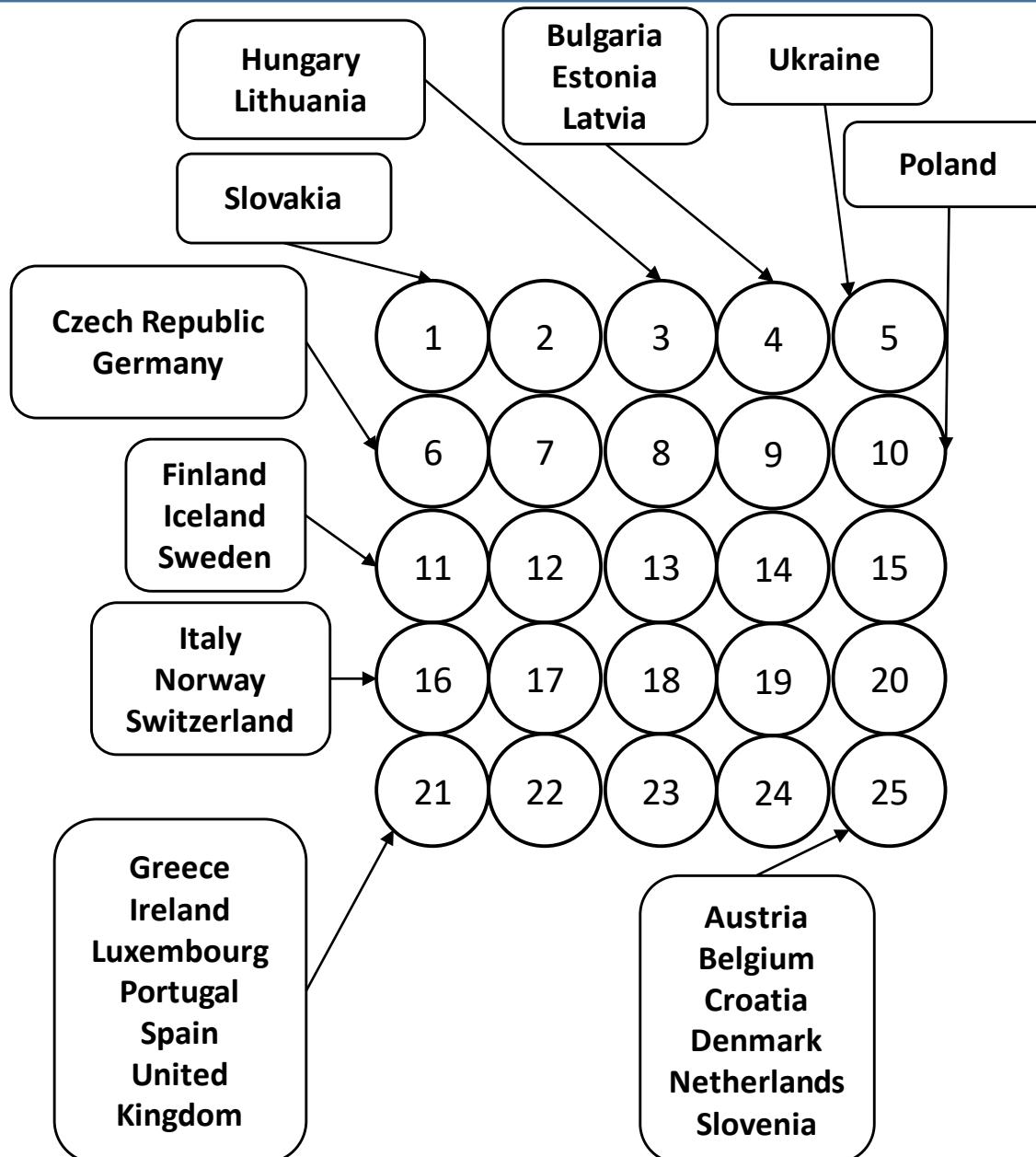


# Sistemas de Inteligencia Artificial 2024 2Q



1	0	2	3	1
2	0	0	0	1
3	0	0	0	0
3	0	0	0	0
6	0	0	0	6

# Sistemas de Inteligencia Artificial 2024 2Q



Area					GDP					Inflation				
0	0	0	0	3	2	0	0	0	10	0	2	0	1	1
1	0	1	1	0	0	0	1	1	1	0	0	0	0	0
0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	20	13	0	0	0	0	18	0	0	1	1
Life_expect					Military					Pop_growth				
0	0	0	1	5	16	0	0	0	0	0	2	4	11	0
0	0	0	0	3	1	0	1	0	1	0	0	0	1	0
0	0	0	1	1	0	0	0	0	2	0	0	0	1	0
0	0	0	0	0	0	0	0	0	0	5	2	0	0	0
15	0	2	0	0	0	0	0	0	0	5	2	0	0	0
Unemployment														
0	0	0	0	0										
0	10	1	0	0										
0	0	1	0	0										
1	0	0	0	1										
13	0	1	0	0										

# Ejercicio 1.2

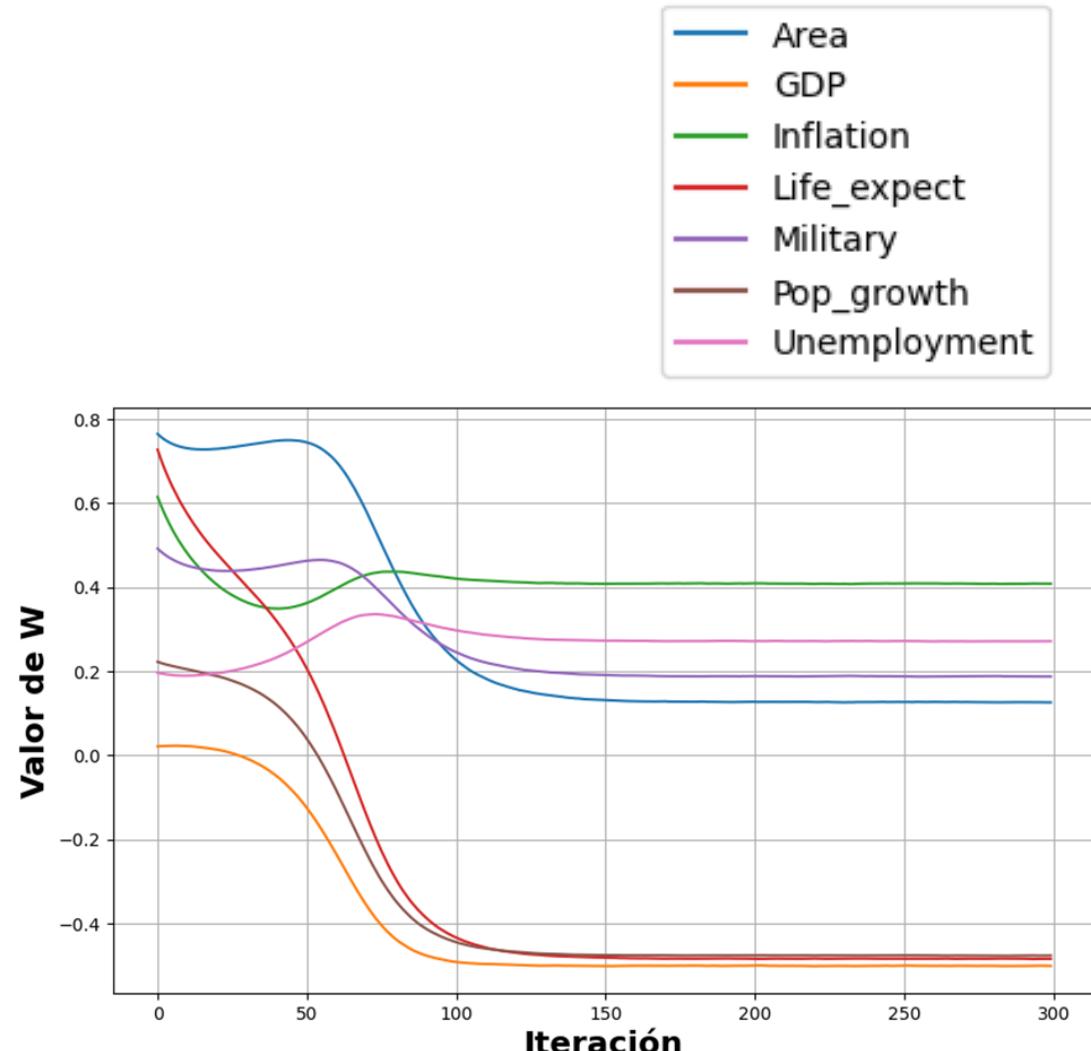
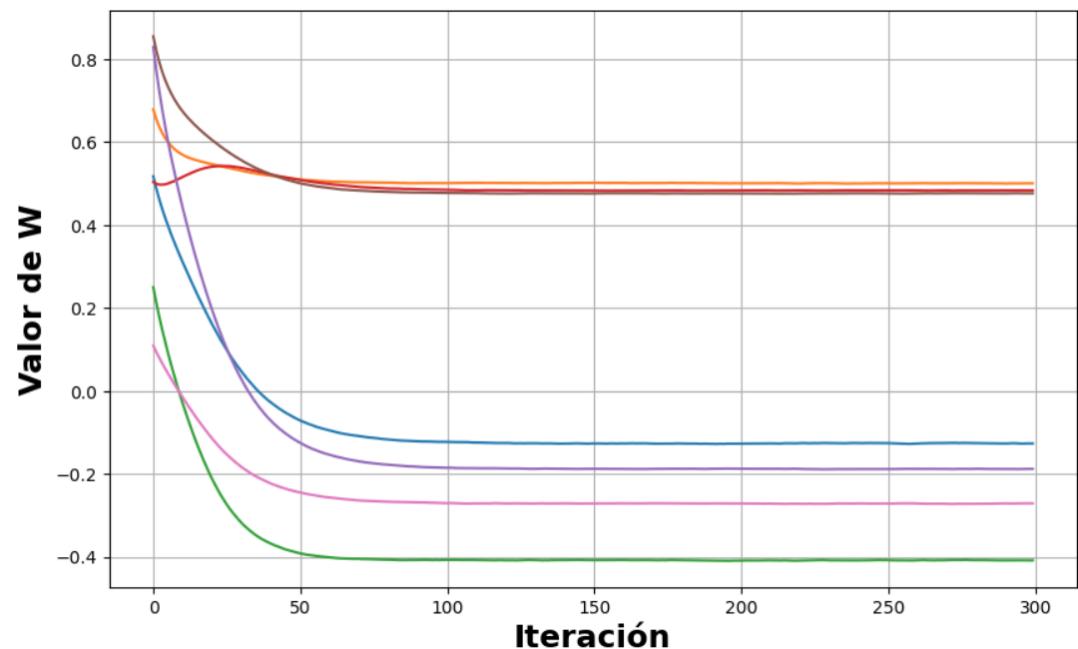
*Modelo de Oja*

$$y_{\text{modelo}}^{\mu} = \sum_{i=1}^n x_i^{\mu} w_i^{\mu}$$

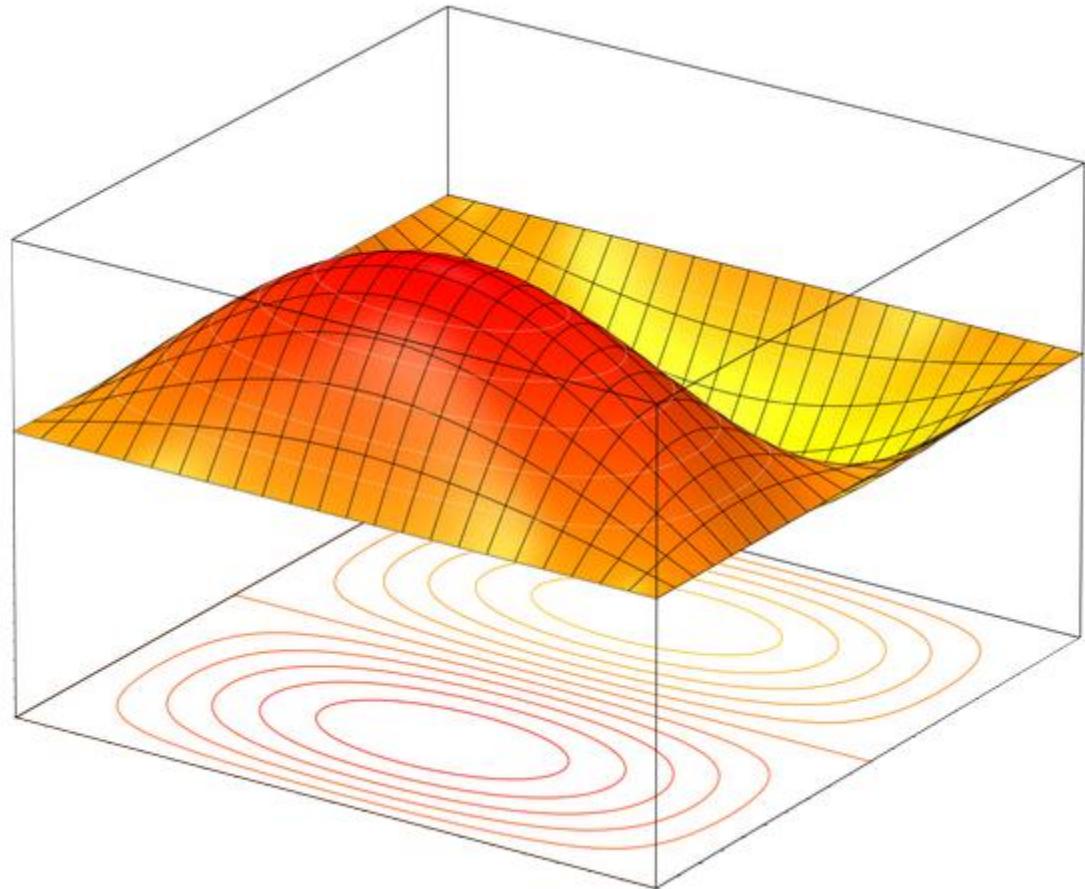
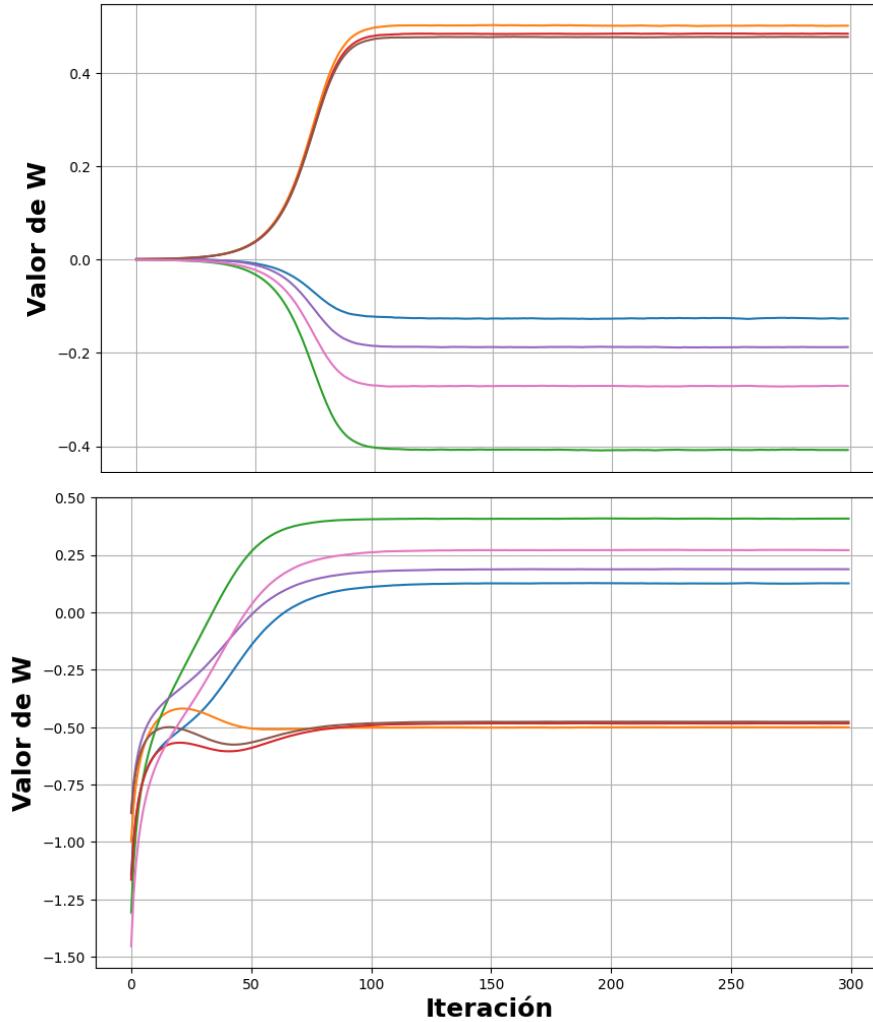
$W_{\text{inicial}} = \text{Distribución uniforme } (0; 1)$

$$W_{\text{nuevo}} = W_{\text{viejo}} + \eta(y_{\text{modelo}})(X_{\text{dato}} - y_{\text{modelo}})W_{\text{viejo}}$$

## Evolución de $W$

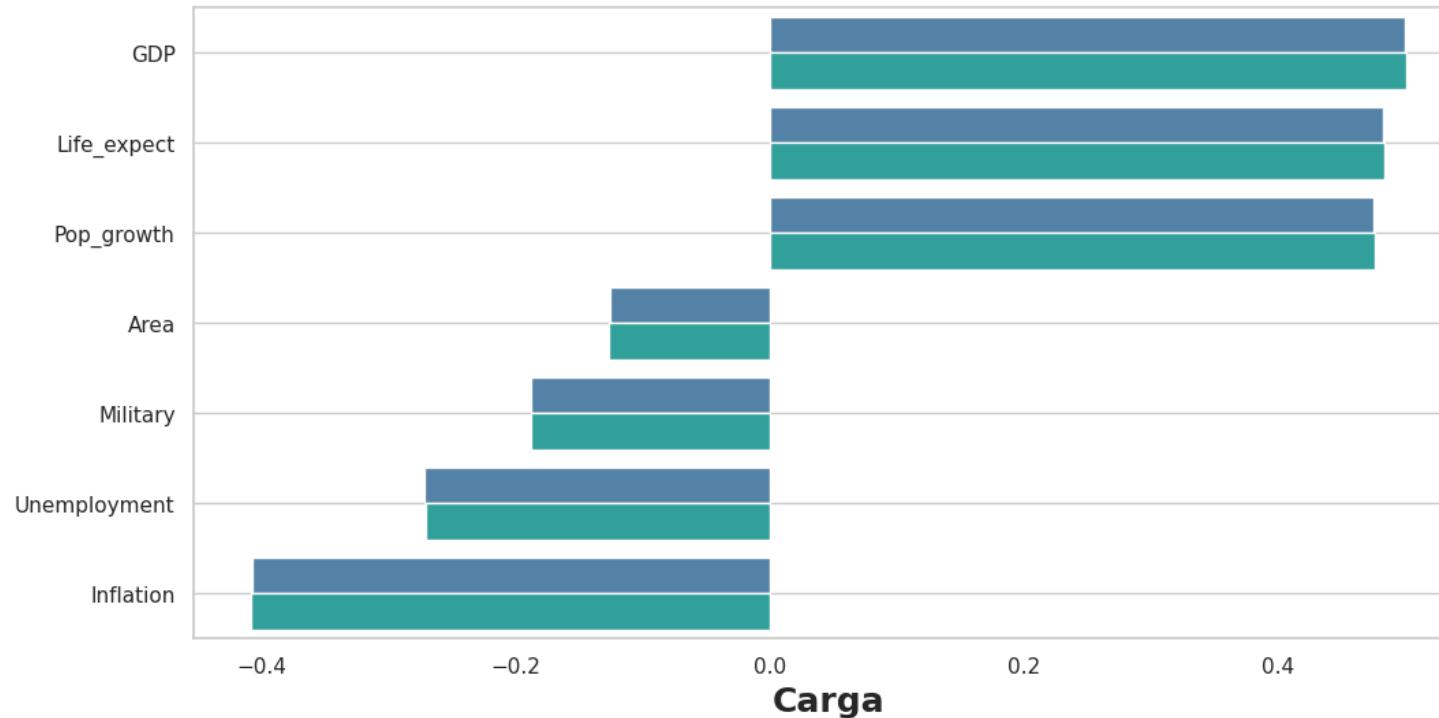


## Evolución de $W$



## Comparacion de los métodos

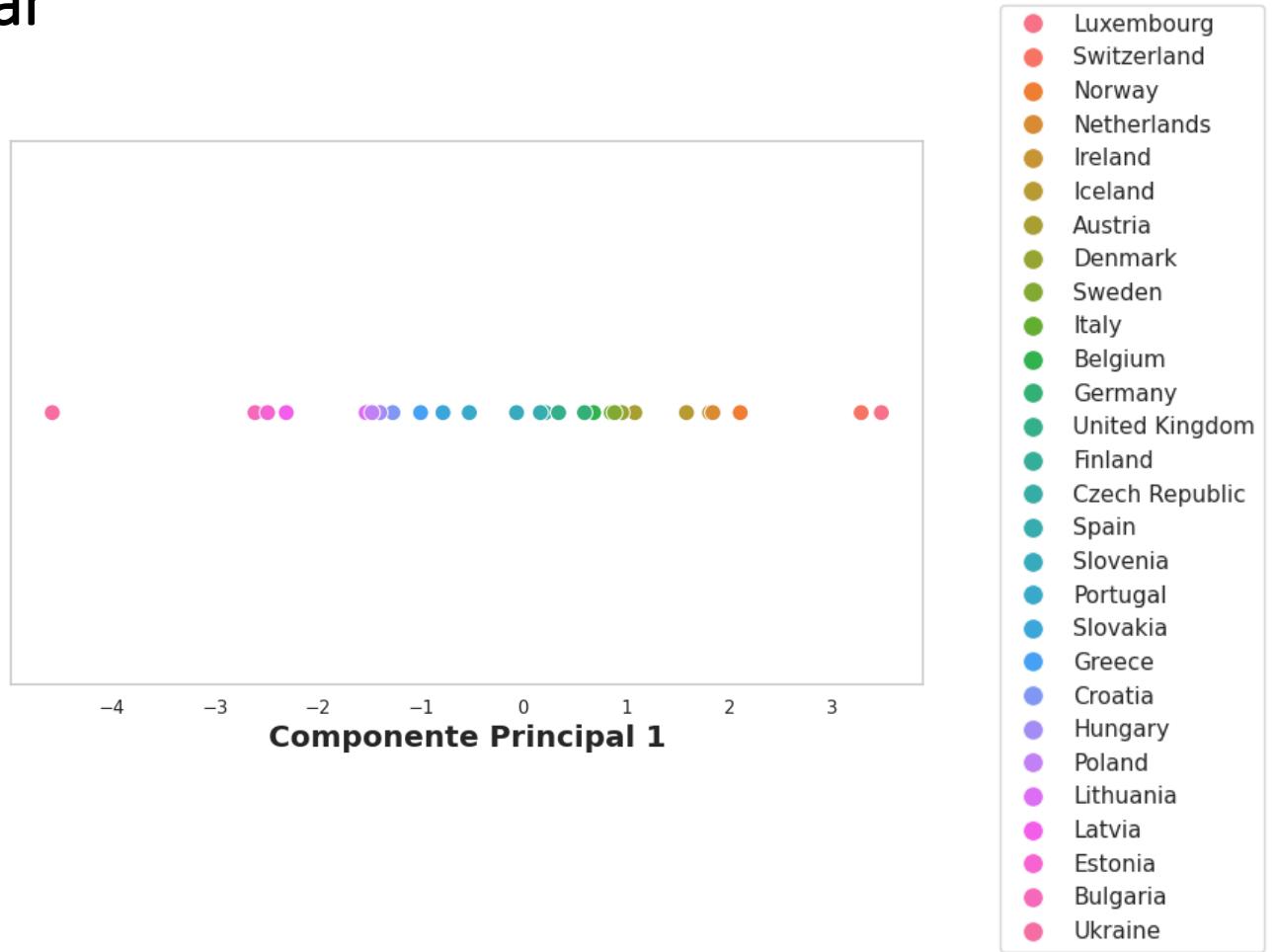
PCA  
Modelo de oja



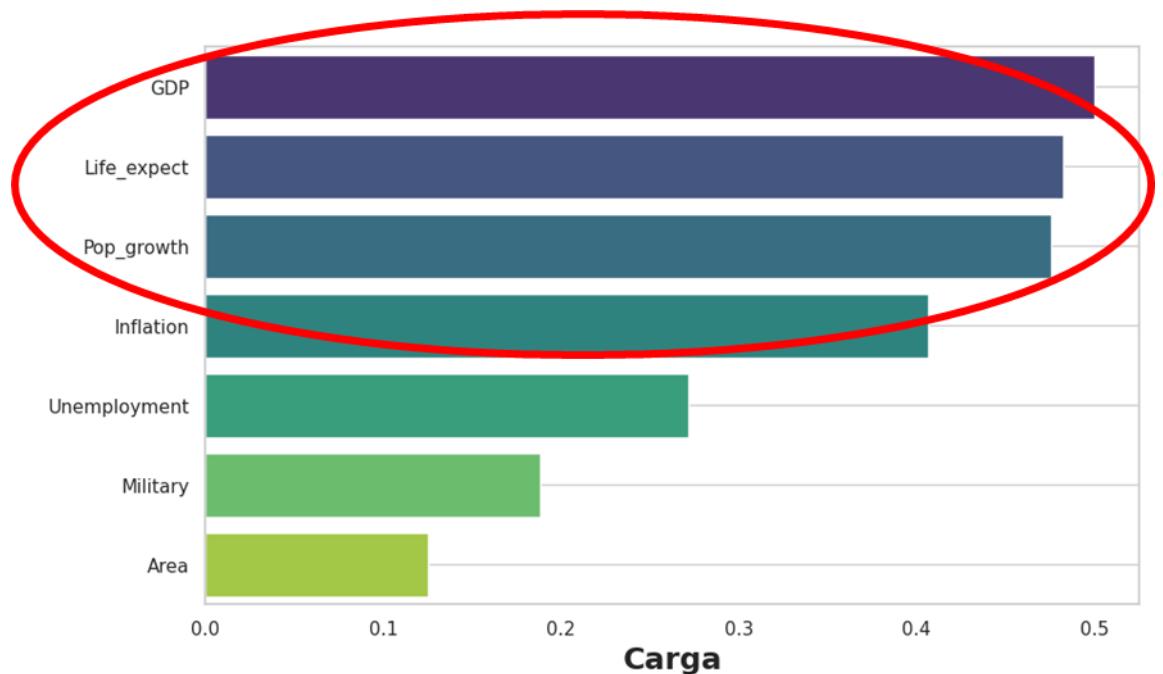
Tiempo Oja: 0.033 +/- 0.0042 segundos

Tiempo PCA: 0.0035 +/- 0.0011 segundos

## PCA Lineal Estandarización estándar



## Desarrollo de las conclusiones

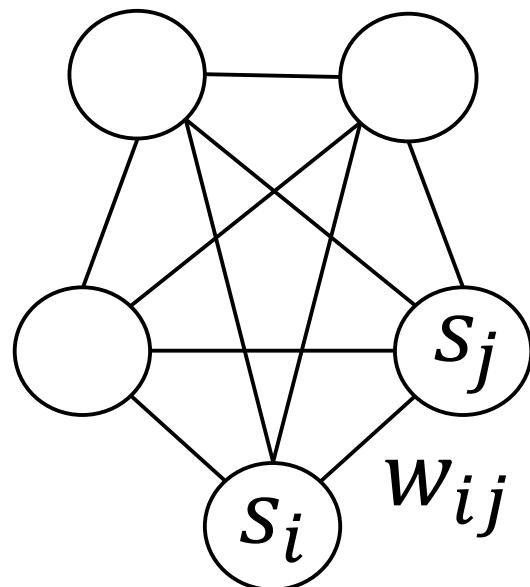


Puede interpretarse como un índice de desarrollo humano

- Una vida larga y saludable, medida por la esperanza de vida al nacer.
- Un nivel de vida decoroso, medido por el GDP (en el set de datos se encuentra per cápita)
- Un crecimiento poblacional sostenible, medido por el crecimiento poblacional.
- Una inflación controlada que no erosiona el poder adquisitivo de las personas.

# Ejercicio 2

## *Modelo de Hopfield*



*N*:nodos

$$a_i = \begin{cases} 1 & \text{si } \sum_j w_{ij} s_j > 0 \\ -1 & \text{si } \sum_j w_{ij} s_j < 0 \end{cases}$$

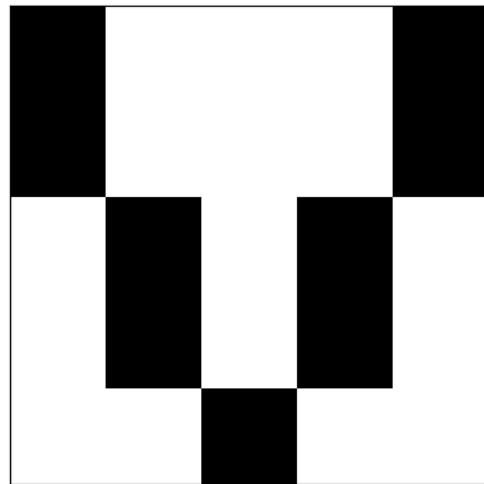
$$\begin{aligned} w_{ii} &= 0 \\ w_{ij} &= w_{ji} \end{aligned}$$

$$w_{ij} = \frac{1}{N} \sum_{\mu=1}^p \xi_i^\mu \xi_j^\mu$$

$$E = -\frac{1}{2} \sum_{i,j} w_{ij} s_i s_j$$

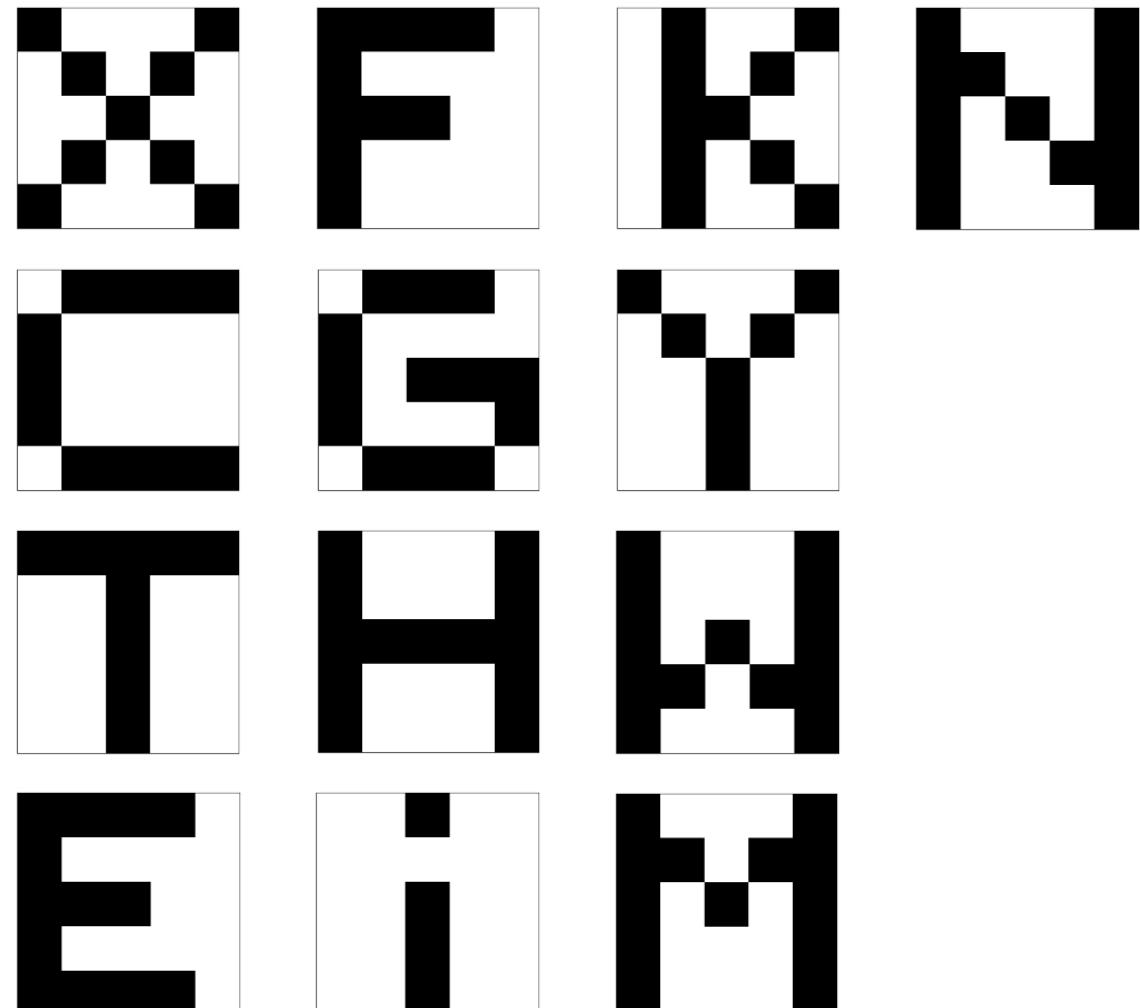
## Patrones

Dimensión:  $5 \times 5$



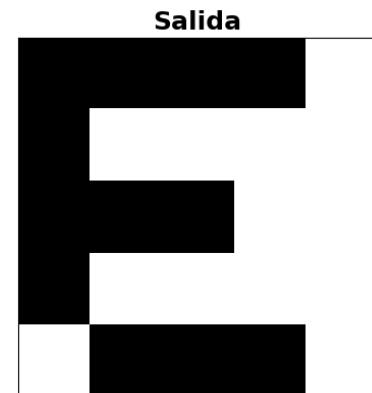
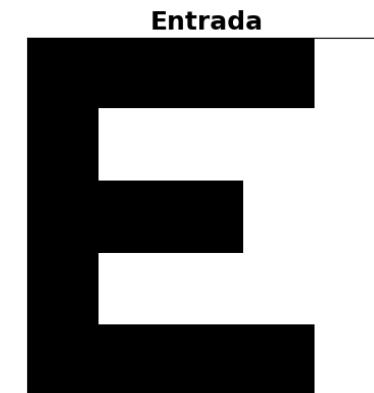
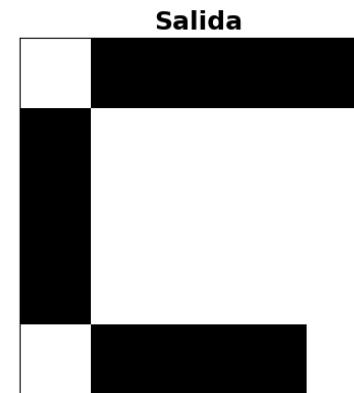
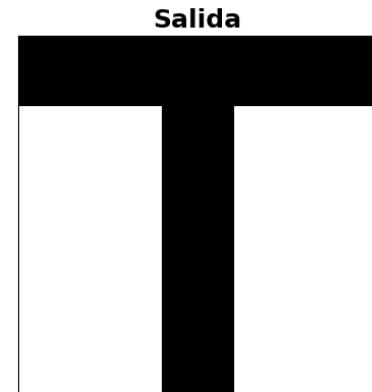
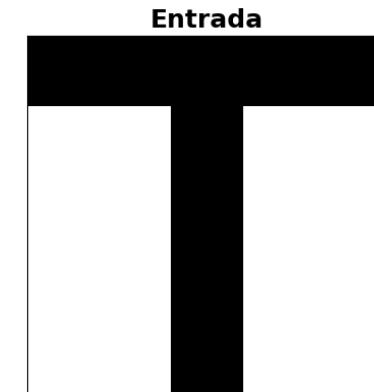
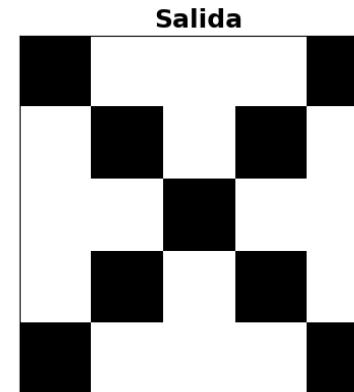
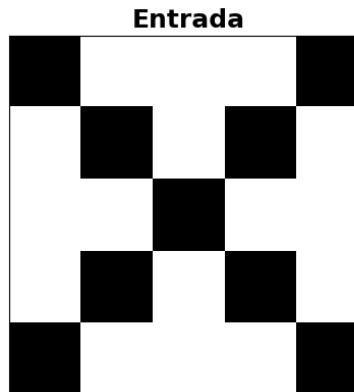
25 neuronas

$w$ : matriz de  $25 \times 25$



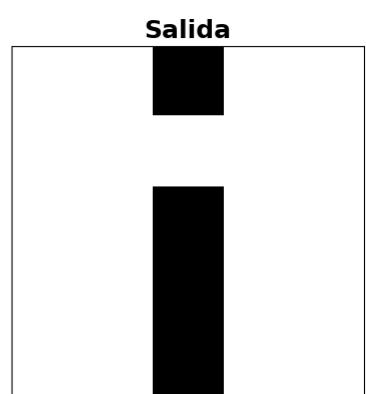
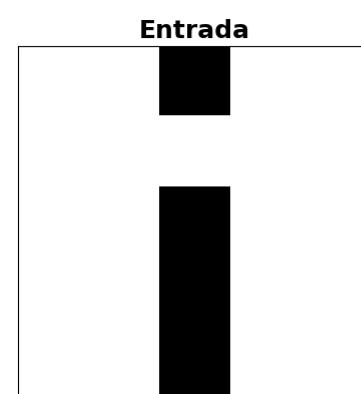
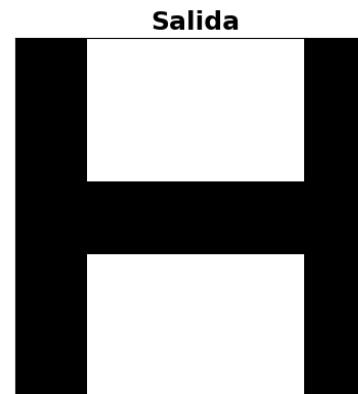
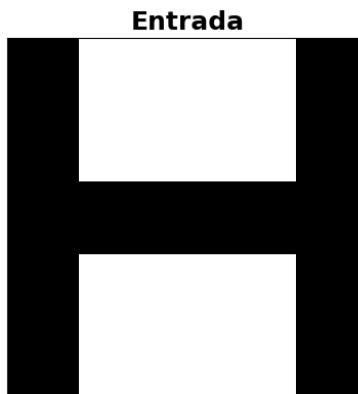
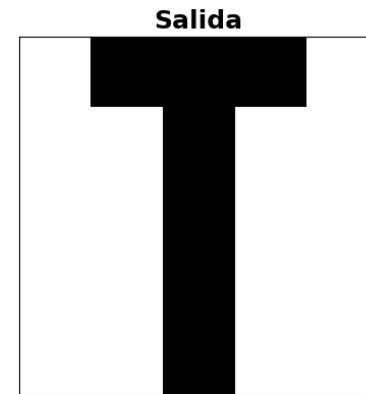
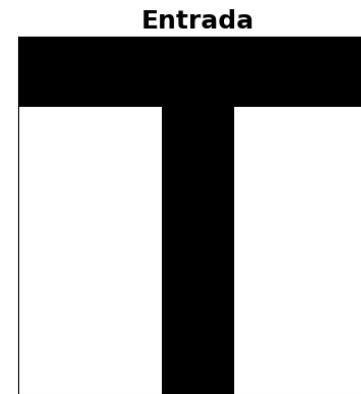
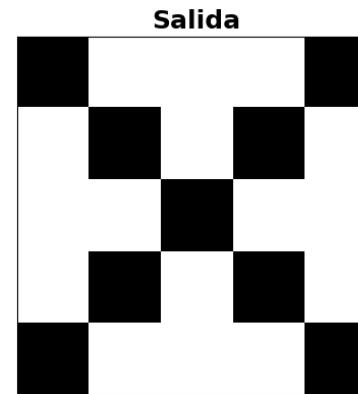
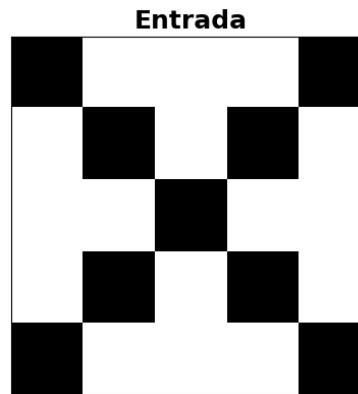
## Resultados

$$w_{ij} = \frac{1}{N} \sum_{\mu=1}^p \xi_i^\mu \xi_j^\mu - diag(\xi_j^\mu \xi_i^\mu)$$



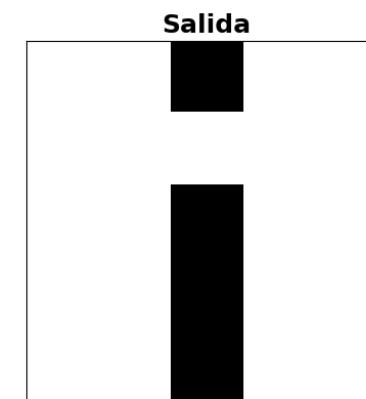
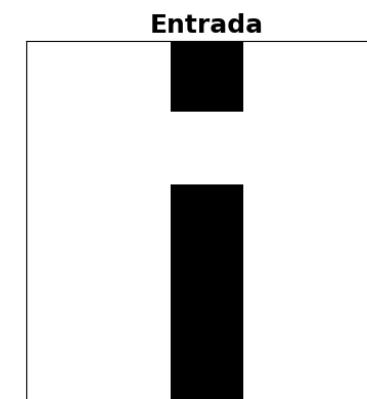
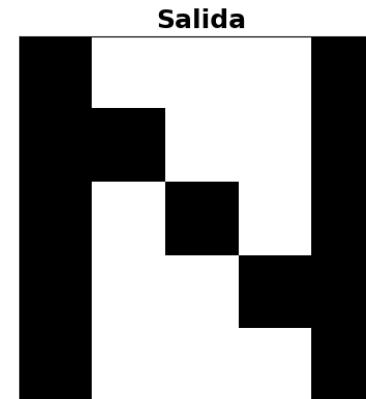
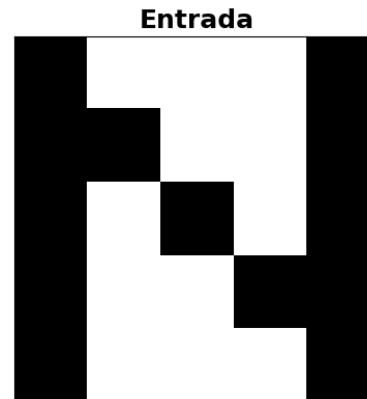
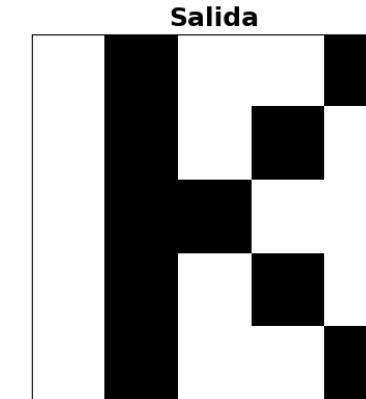
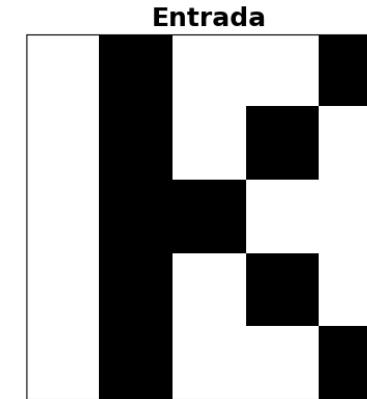
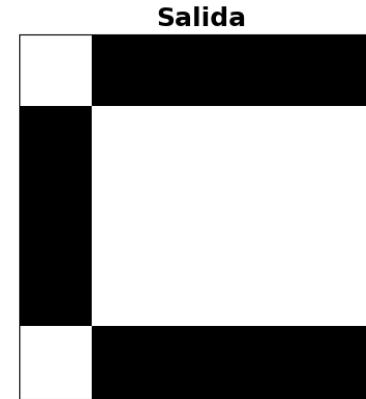
## Resultados

*Diferentes patrones*



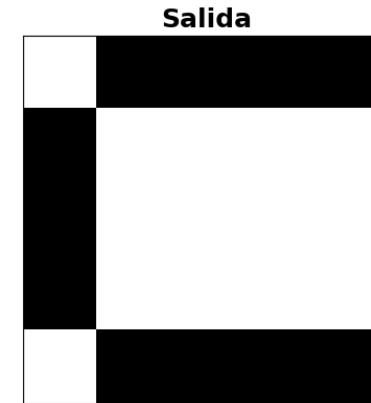
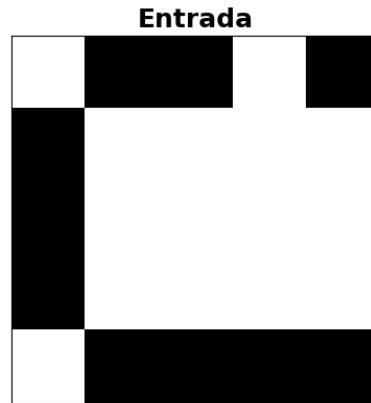
## Resultados

*Diferentes patrones*

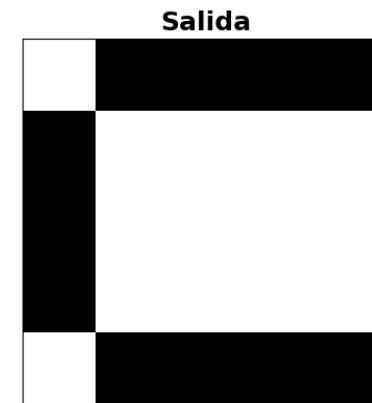
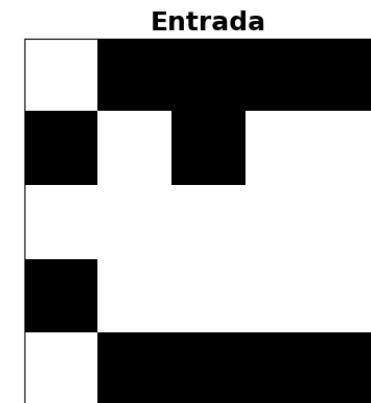


## Patrón de consulta con alteraciones aleatorias

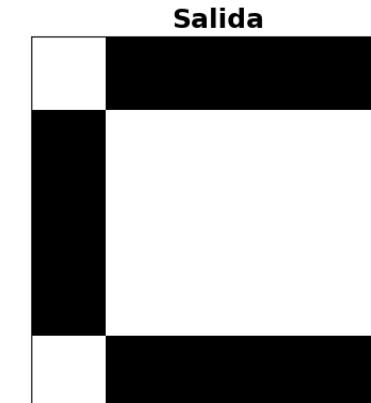
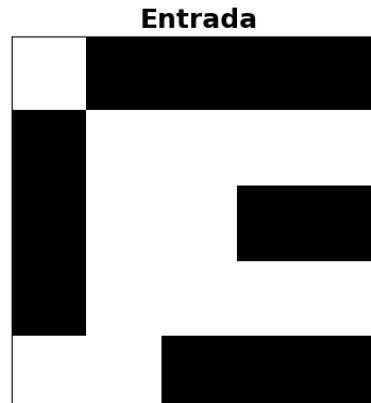
*1 alteración*



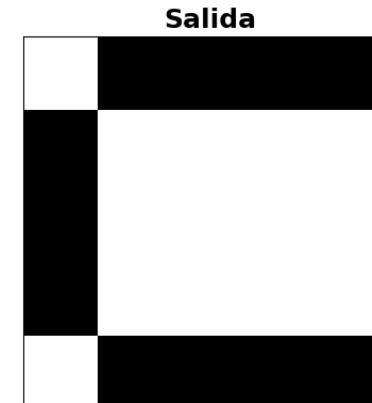
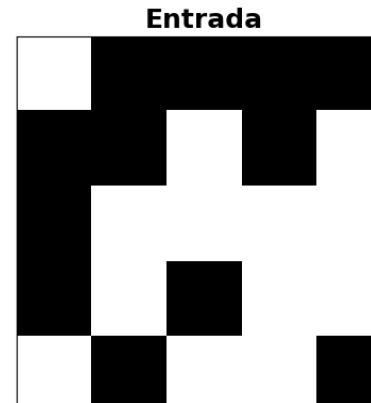
*2 alteraciones*



*3 alteraciones*

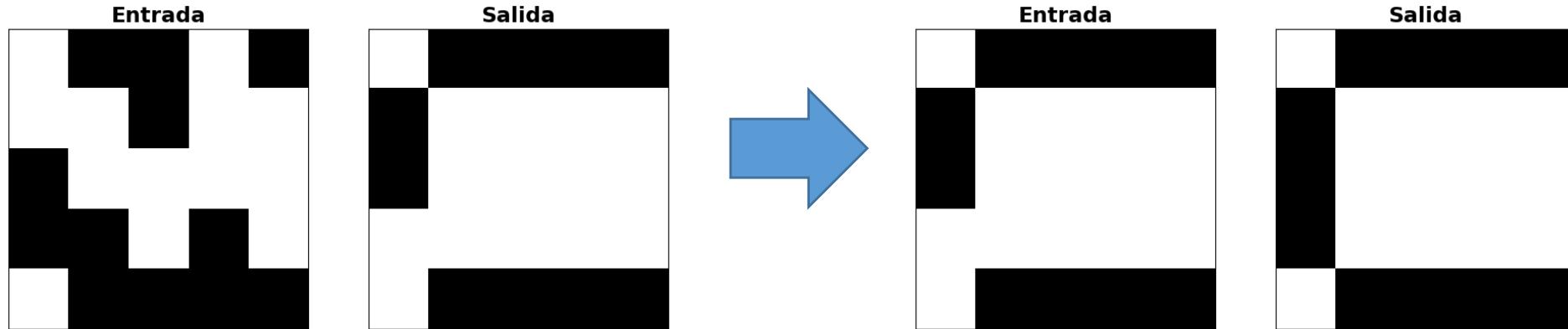


*5 alteraciones*

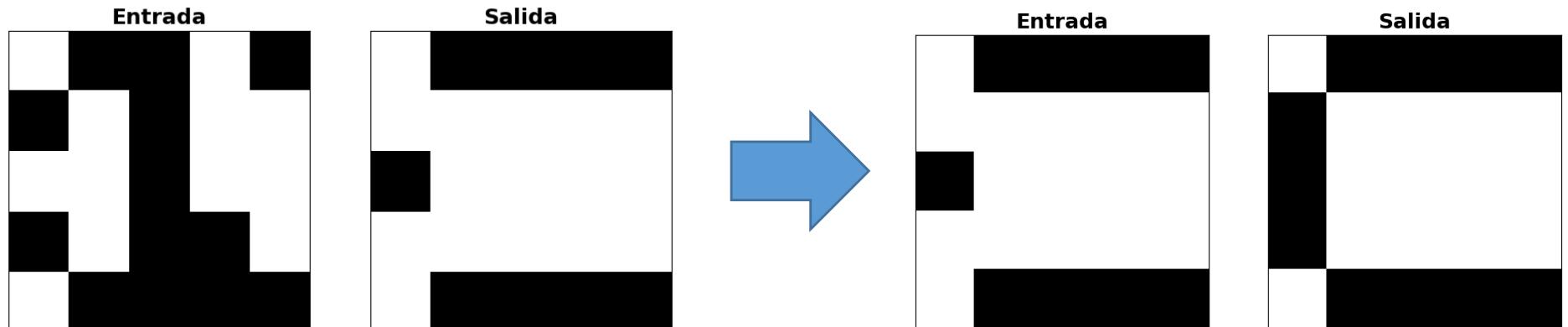


## Patrón de consulta con alteraciones aleatorias

*5 alteraciones*

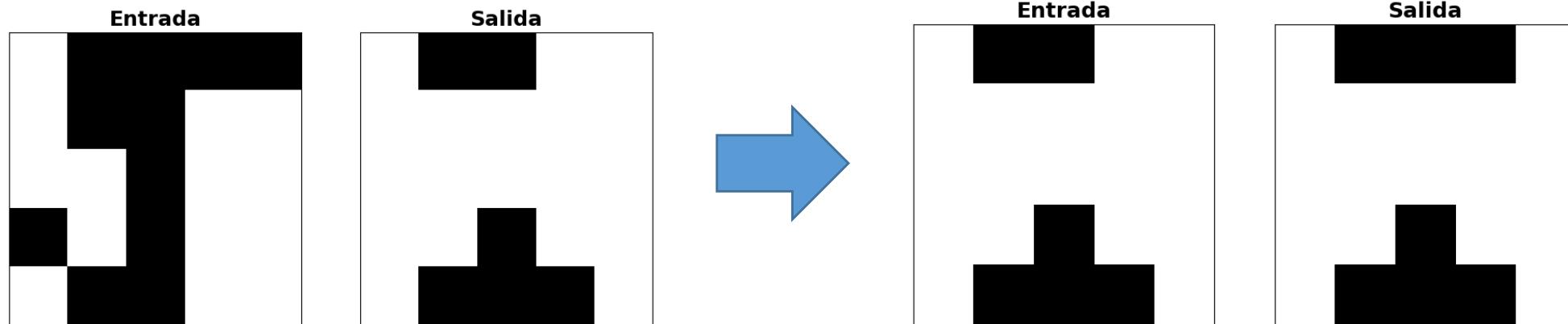


*6 alteraciones*



## Patrón de consulta con alteraciones aleatorias

*8 alteraciones*



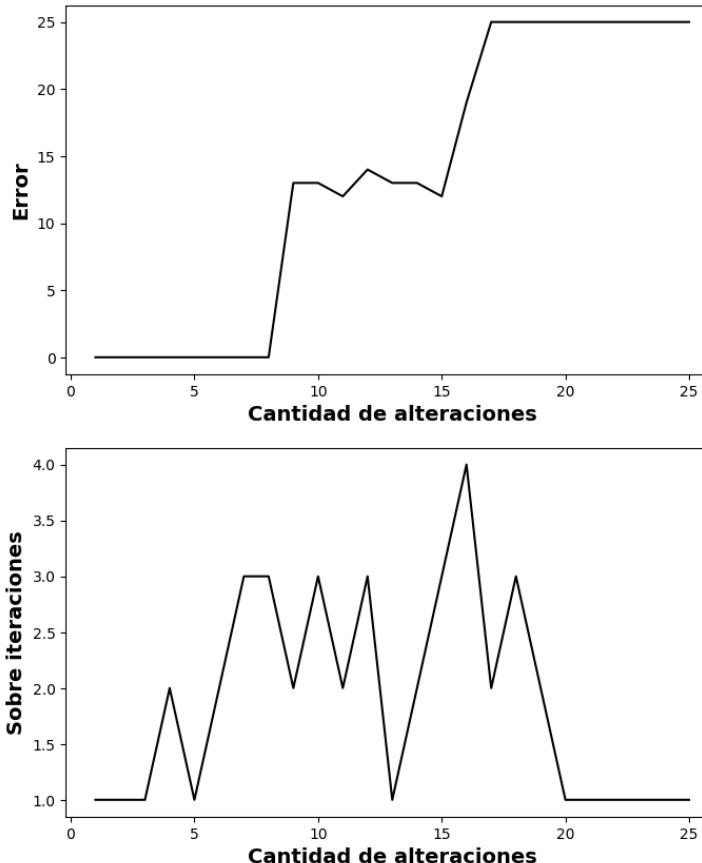
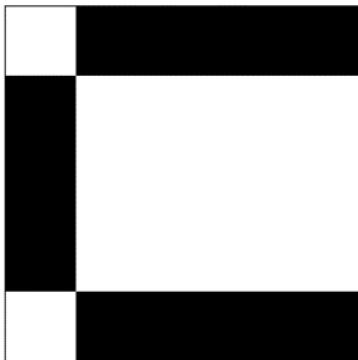
## Patrón de consulta con alteraciones aleatorias

*Se define el error como la diferencia entre el patrón sin alteración y la salida del modelo*

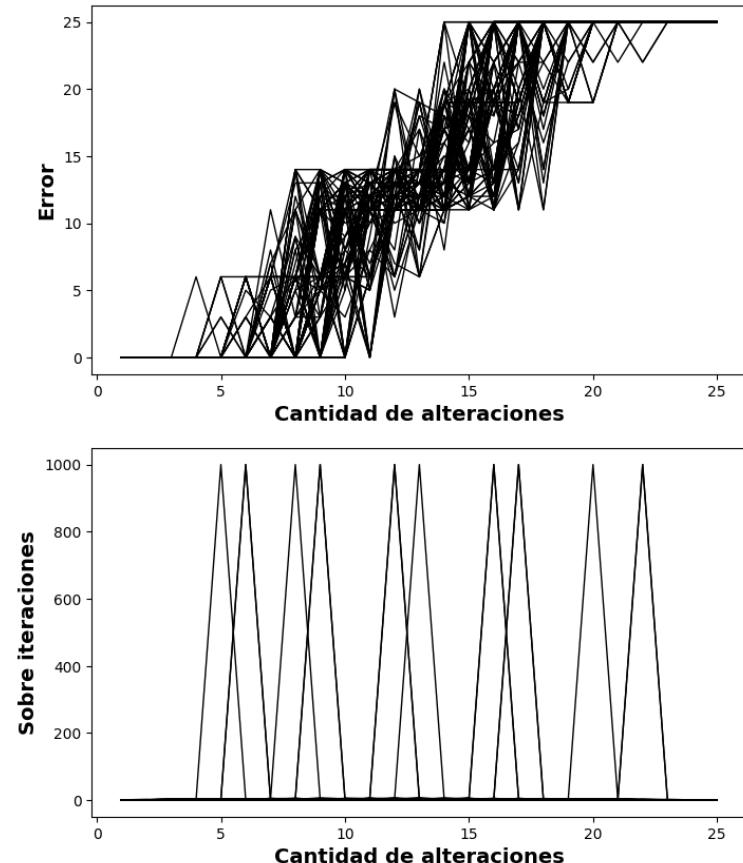
*Se considera:*

- Un valor no puede alterarse mas de una vez*
- Se repite el modelo hasta que no se modifique la salida*

## Patrón de consulta con alteraciones aleatorias

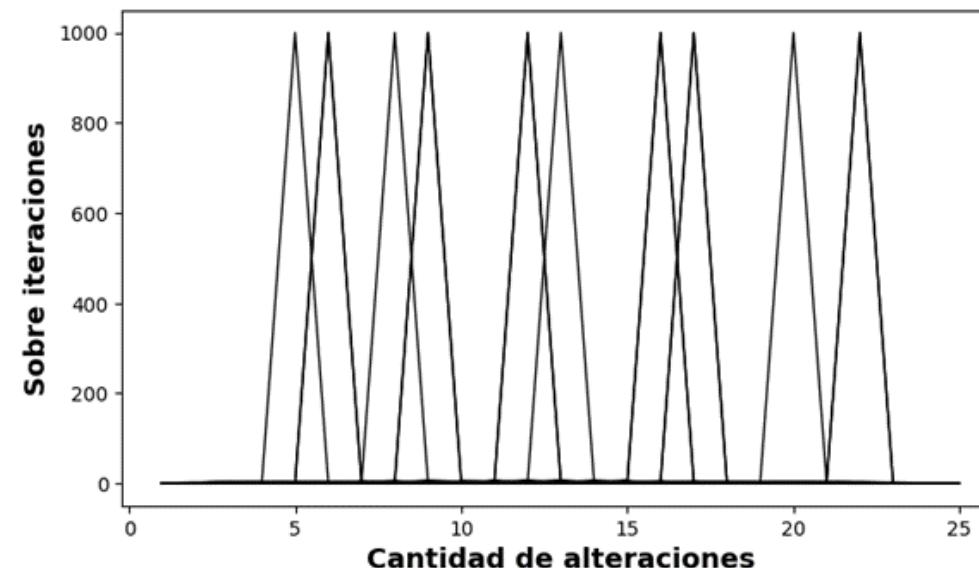
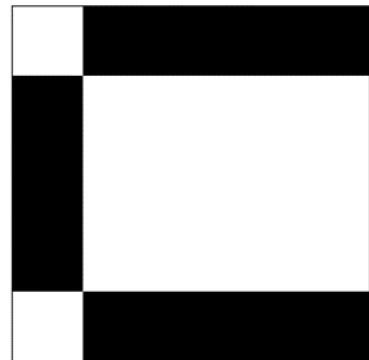


1 corrida

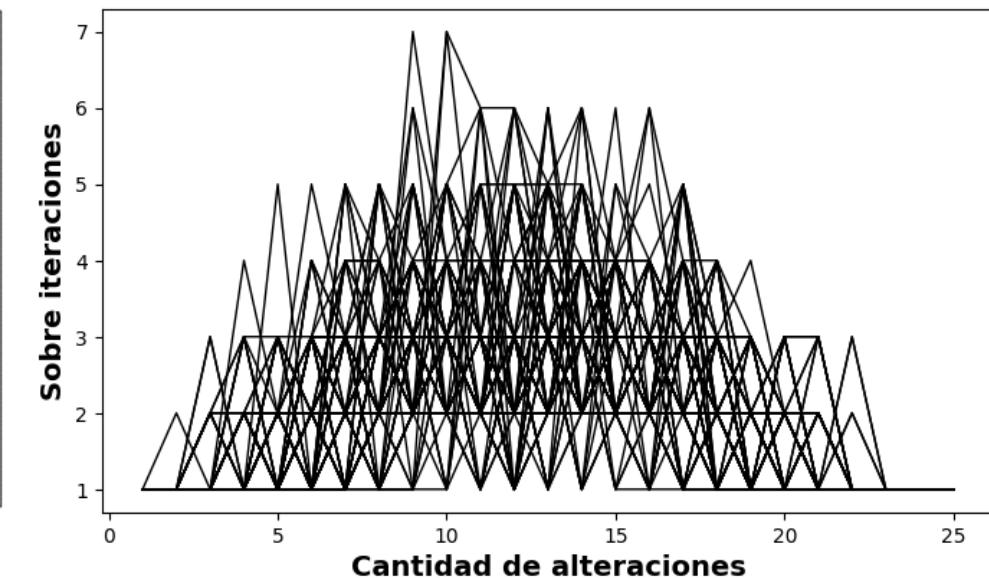


100 corridas

## Patrón de consulta con alteraciones aleatorias

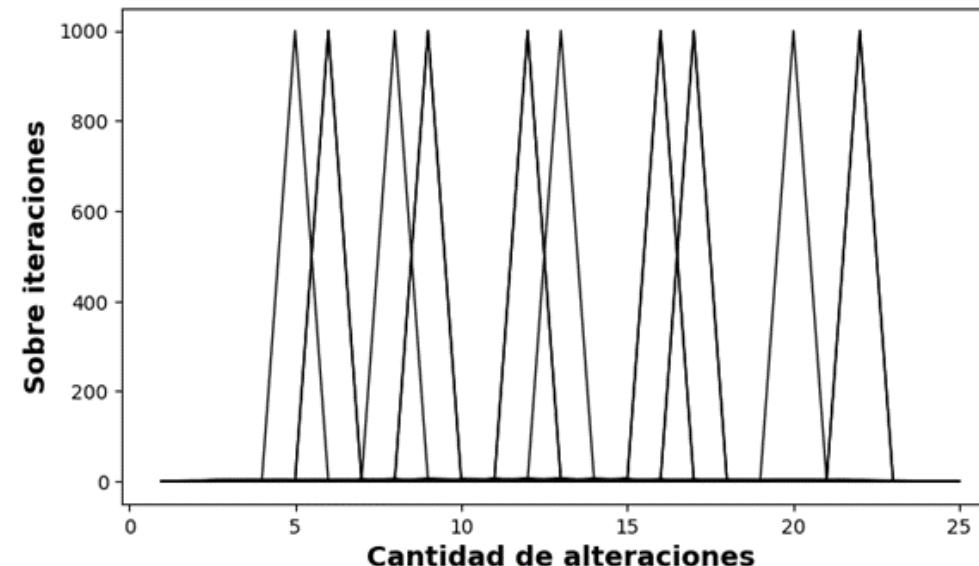
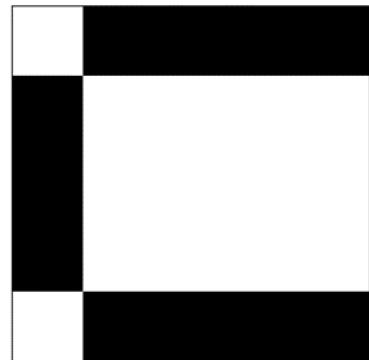


1 corrida

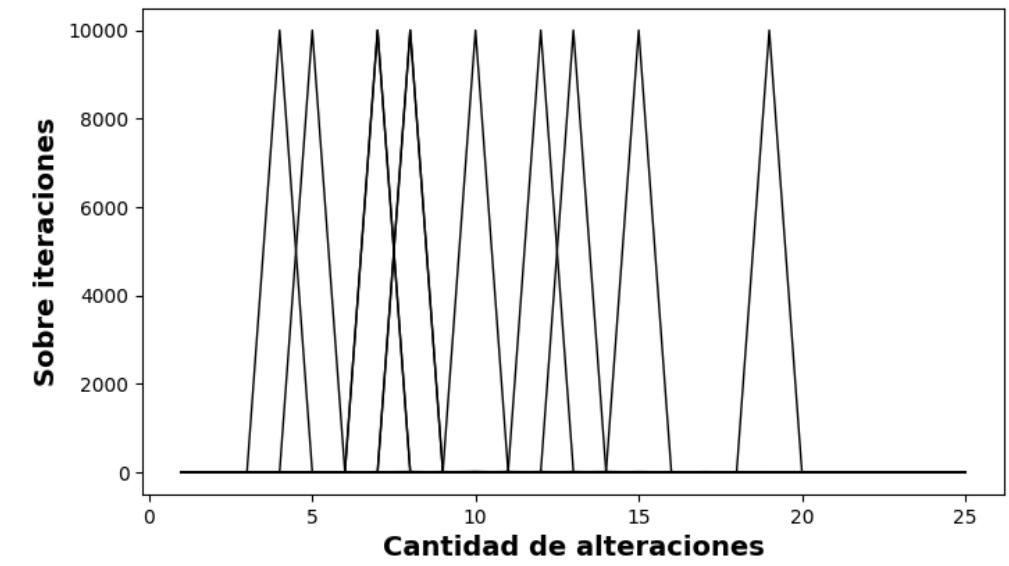


100 corridas

## ¿Patrón iterativo?



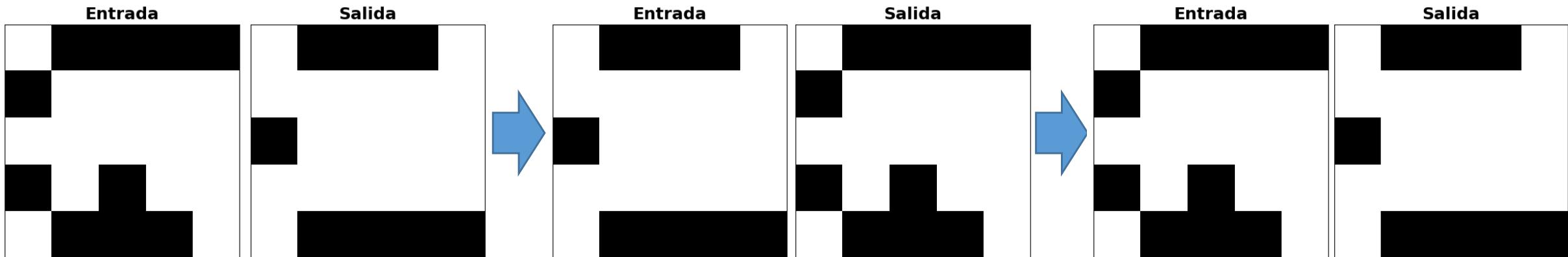
100 corridas



100 corridas

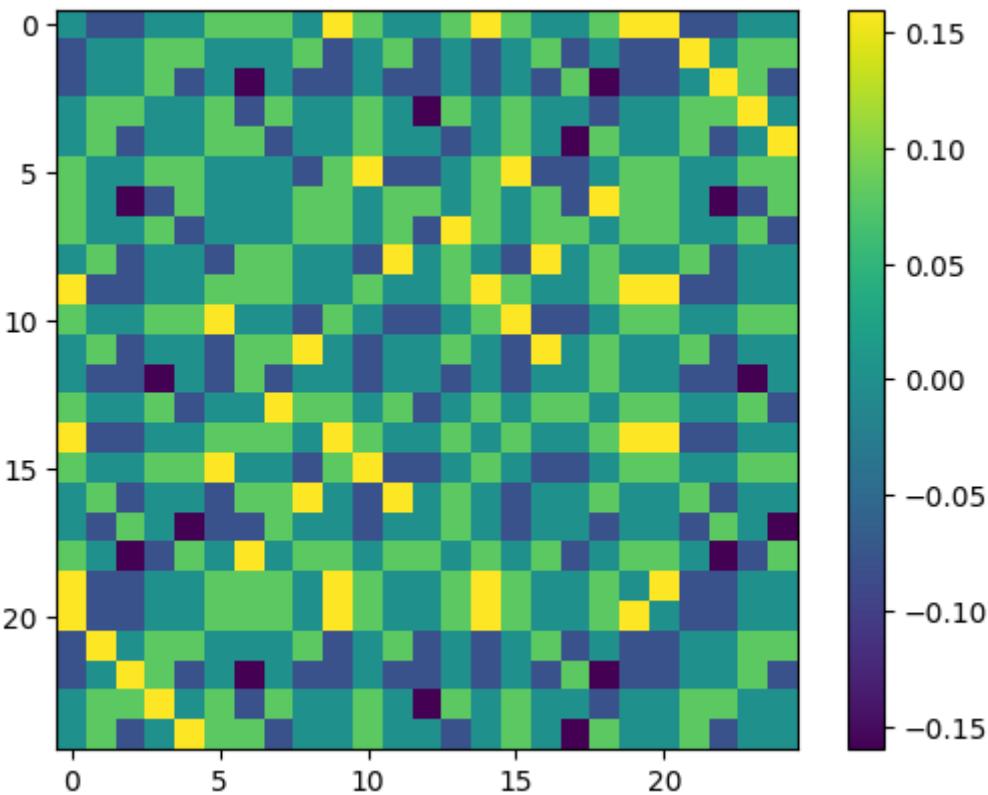
## ¿Patrón iterativo?

*Se toma aquel patrón a las 1000 corridas:*



## ¿Patrón iterativo?

*Se diagnostica  $W$*



*$W$  es simétrica*

*$W[i, i] = 0$  con  $i = 1, 2, \dots, N$*

## ¿Patrón iterativo?



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0893-6080/97 \$17.00+.00

CONTRIBUTED ARTICLE

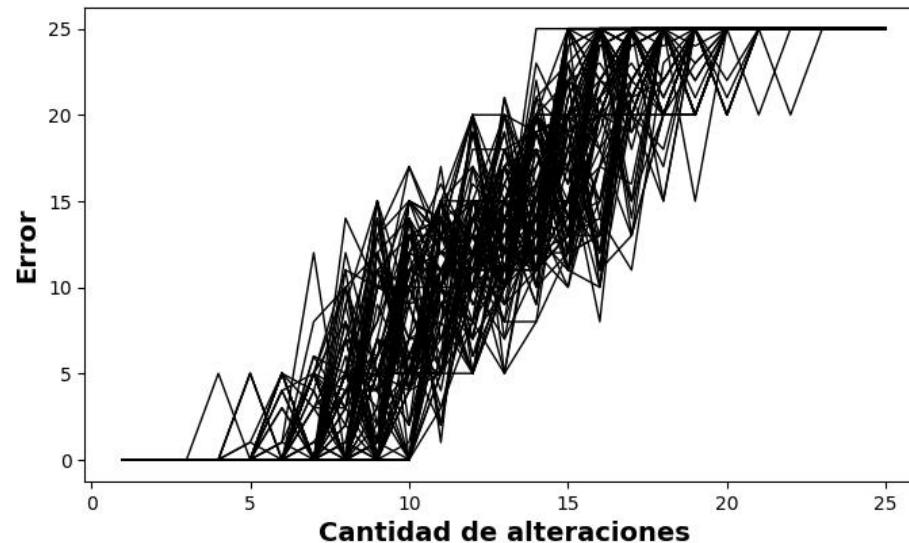
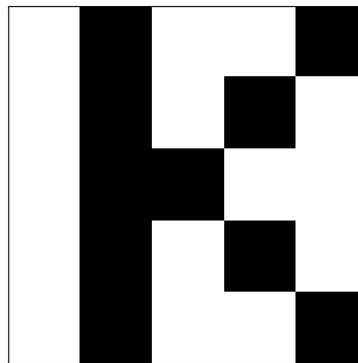
### The Stability of the Generalized Hopfield Networks in Randomly Asynchronous Mode

$$F_i(X) = I(H_i(X)) = \begin{cases} 1 & \text{if } H_i(X) \geq 0 \\ 0 & \text{otherwise} \end{cases}$$

**THEOREM 2.** *A GHN with nonnegative weights is strictly stable.*

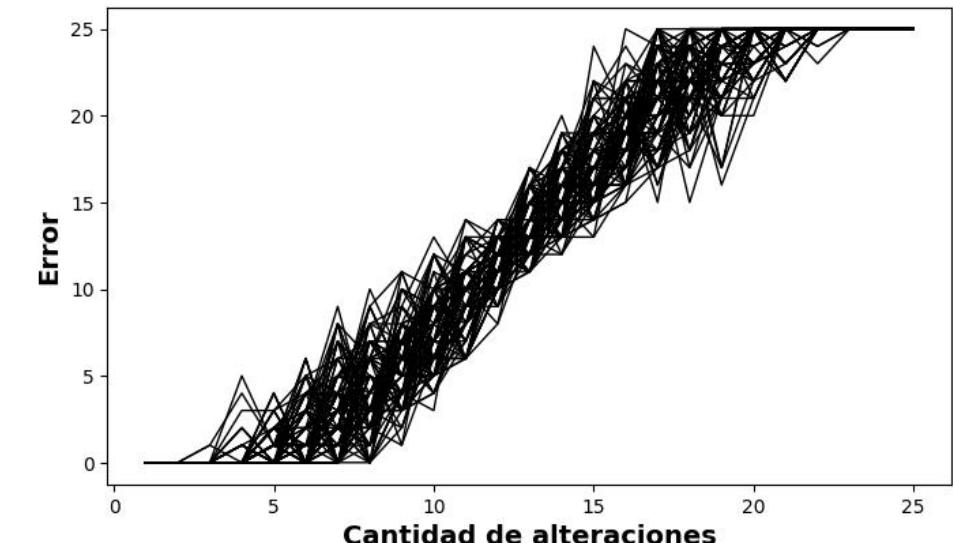
*Se puede explorar la opción de reformular la función de activación y re evaluar la situación*

## Patrón de consulta con alteraciones aleatorias



100 *iteraciones*

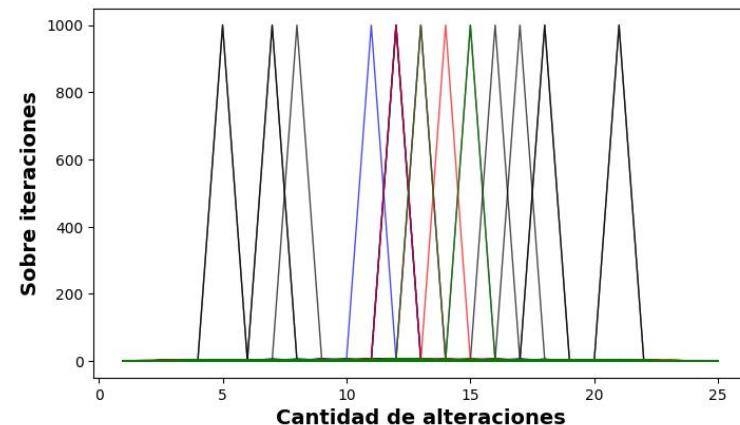
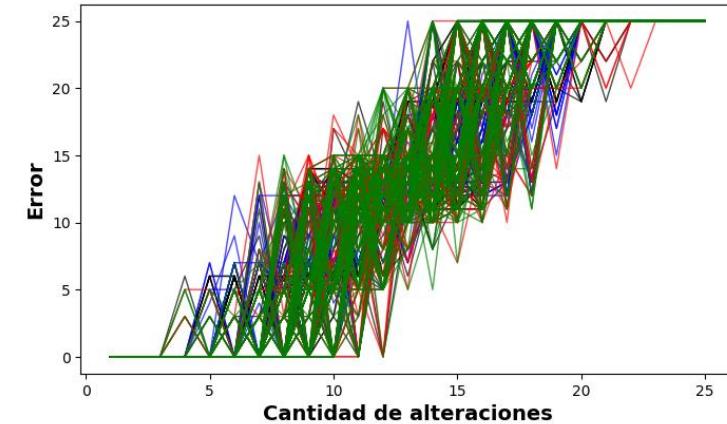
*Sin sobre iteraciones:*



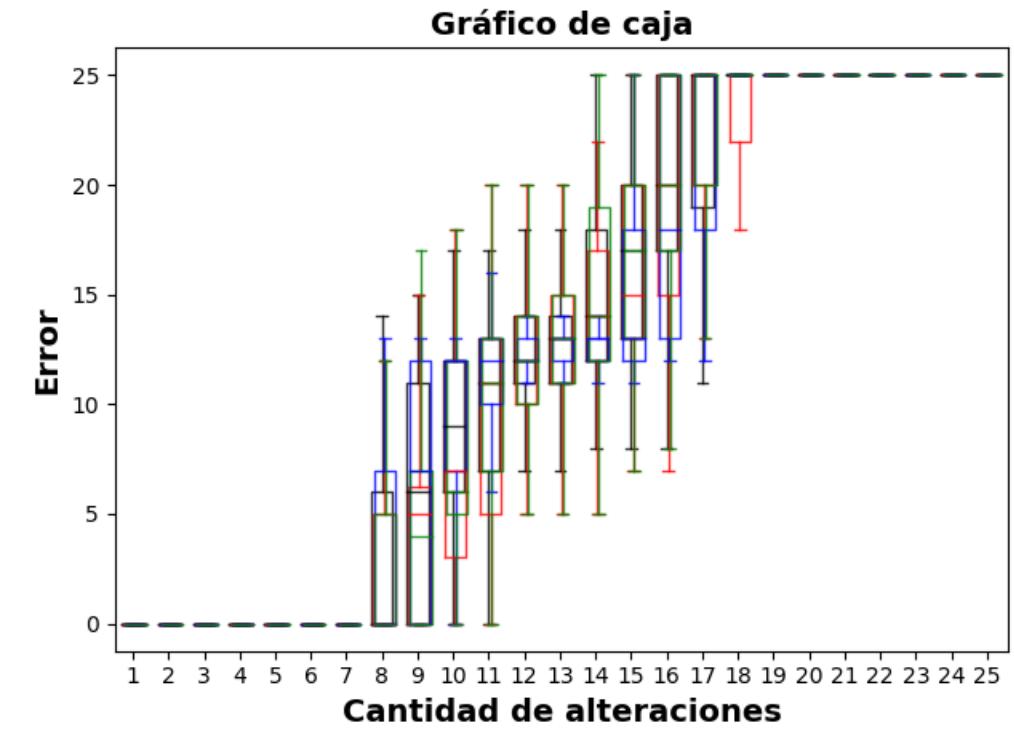
100 *iteraciones*

## Patrón de consulta con alteraciones aleatorias

- Patrón 1
- Patrón 2
- Patrón 3
- Patrón 4

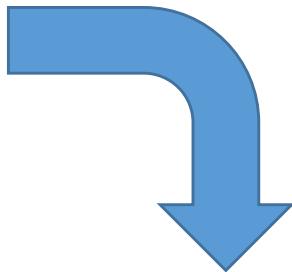
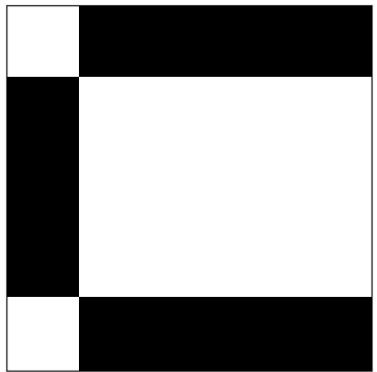


100 *iteraciones*

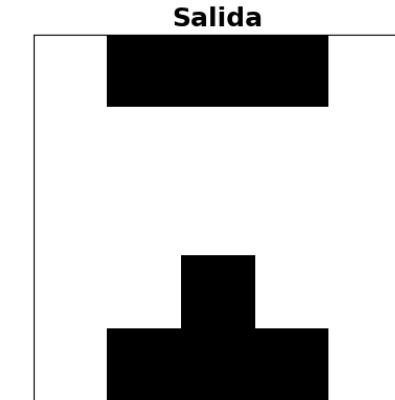
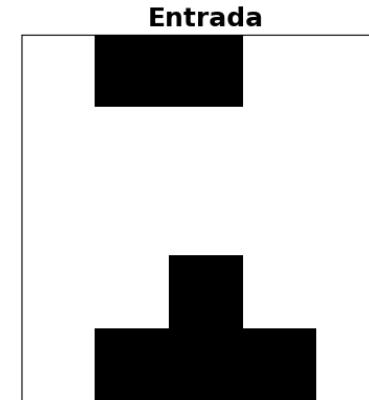
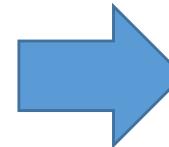
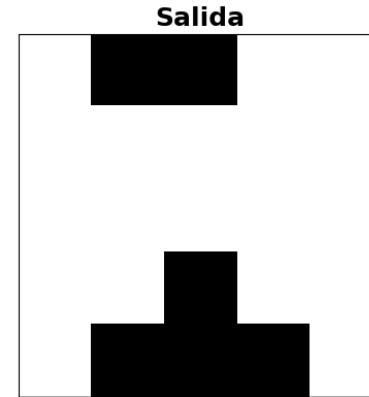
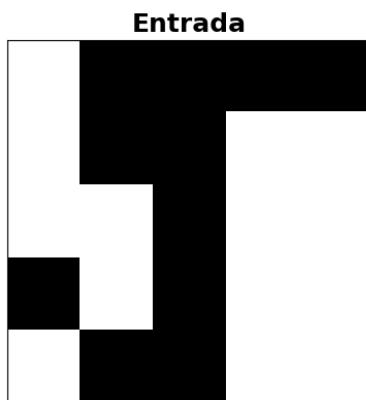


1000 *iteraciones*

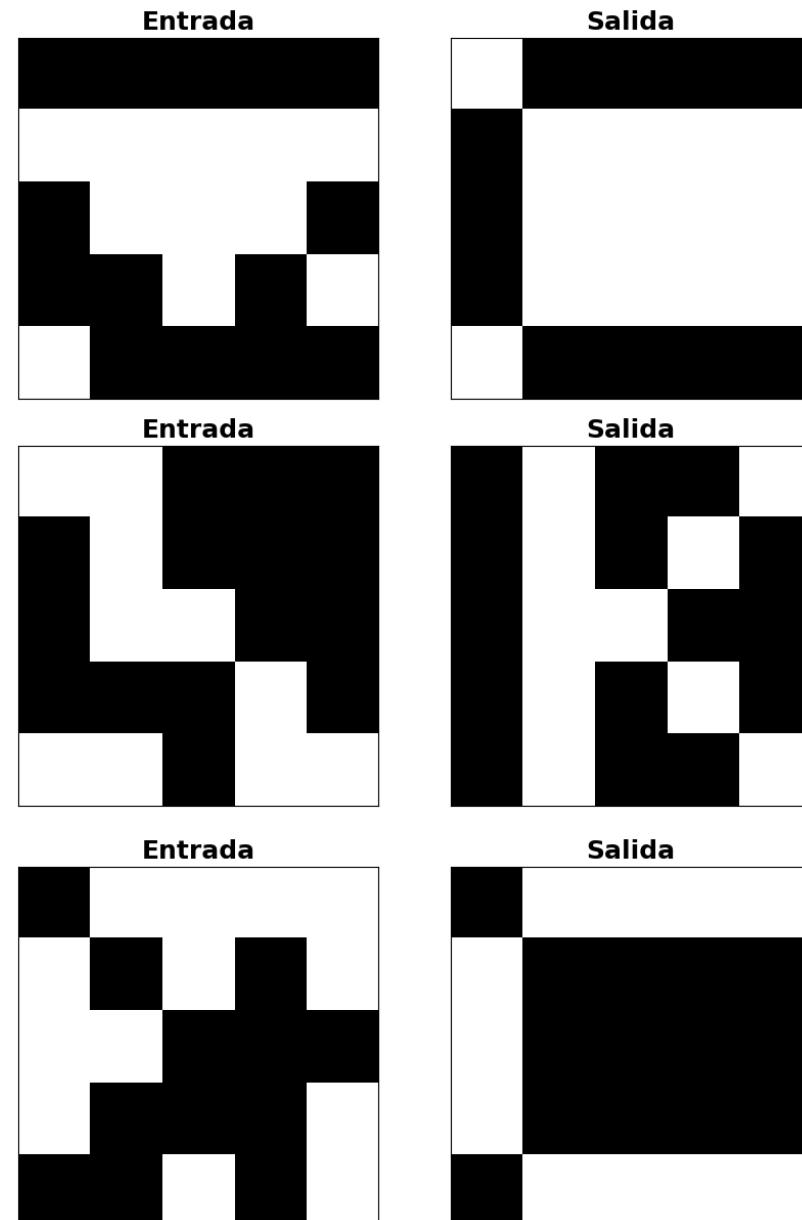
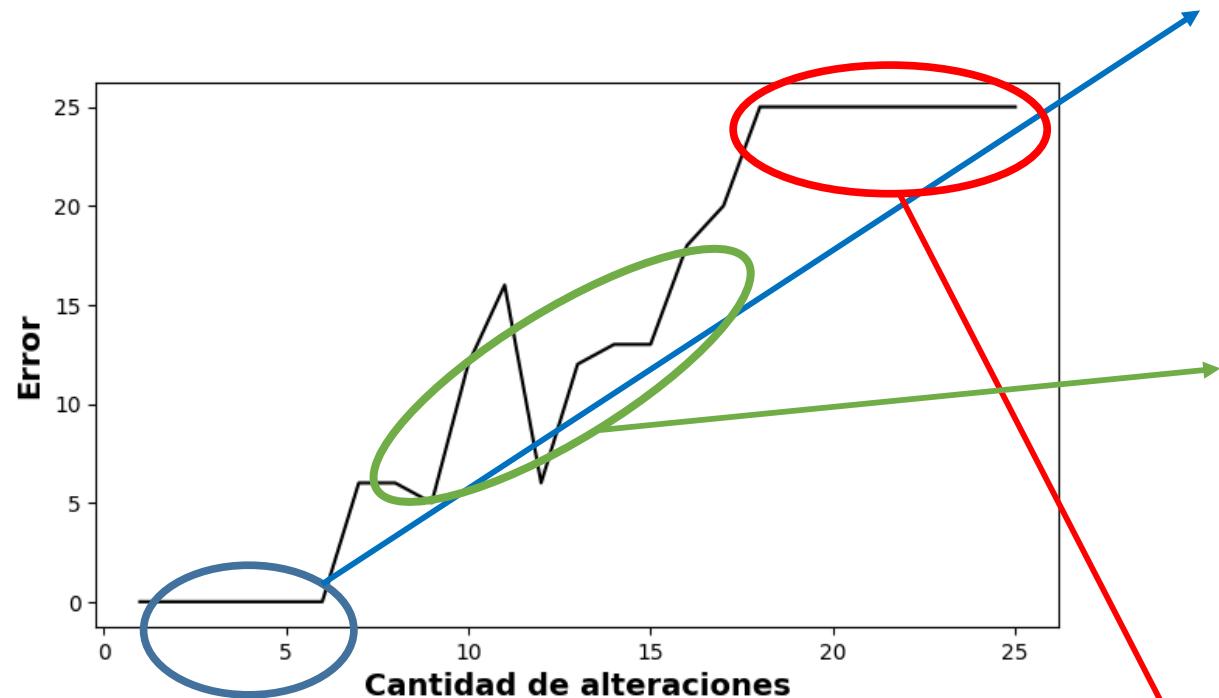
## Estados espúreos



*8 alteraciones*

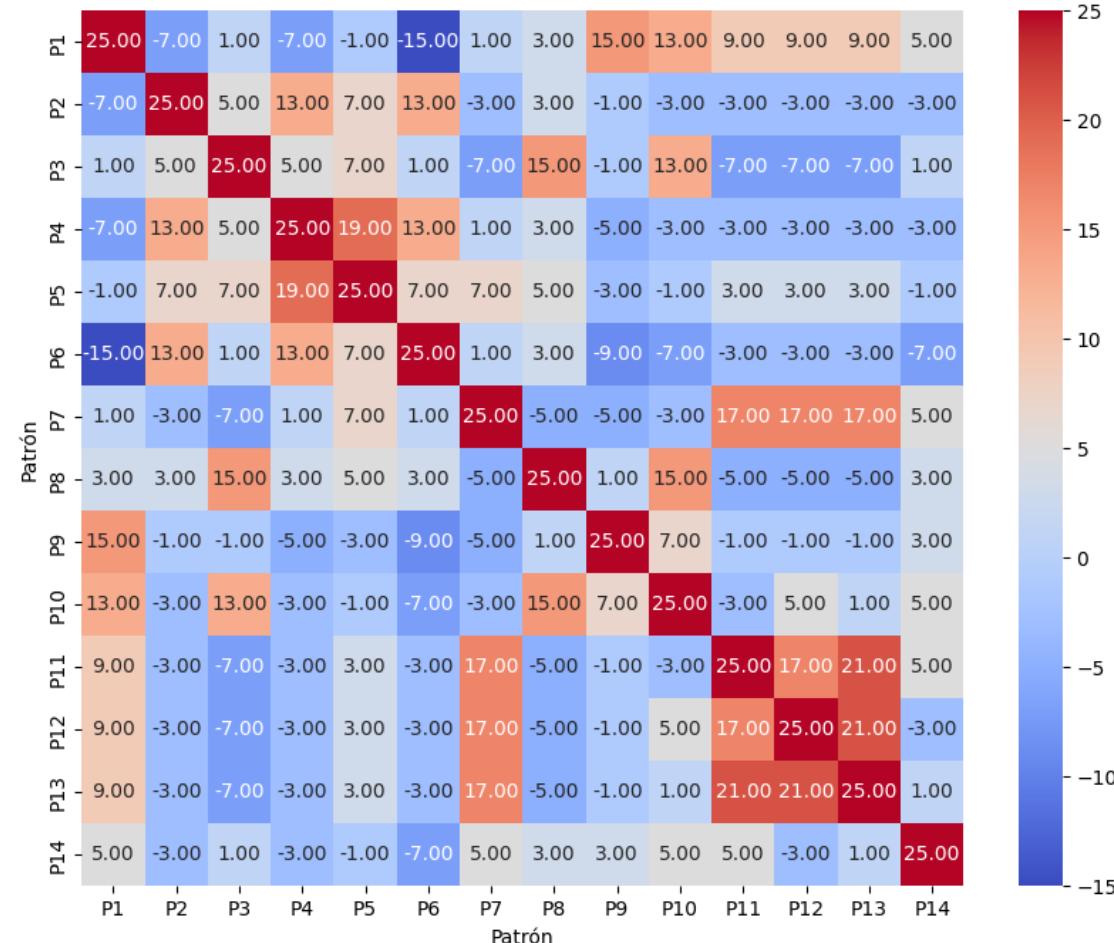


## Estados espúreos

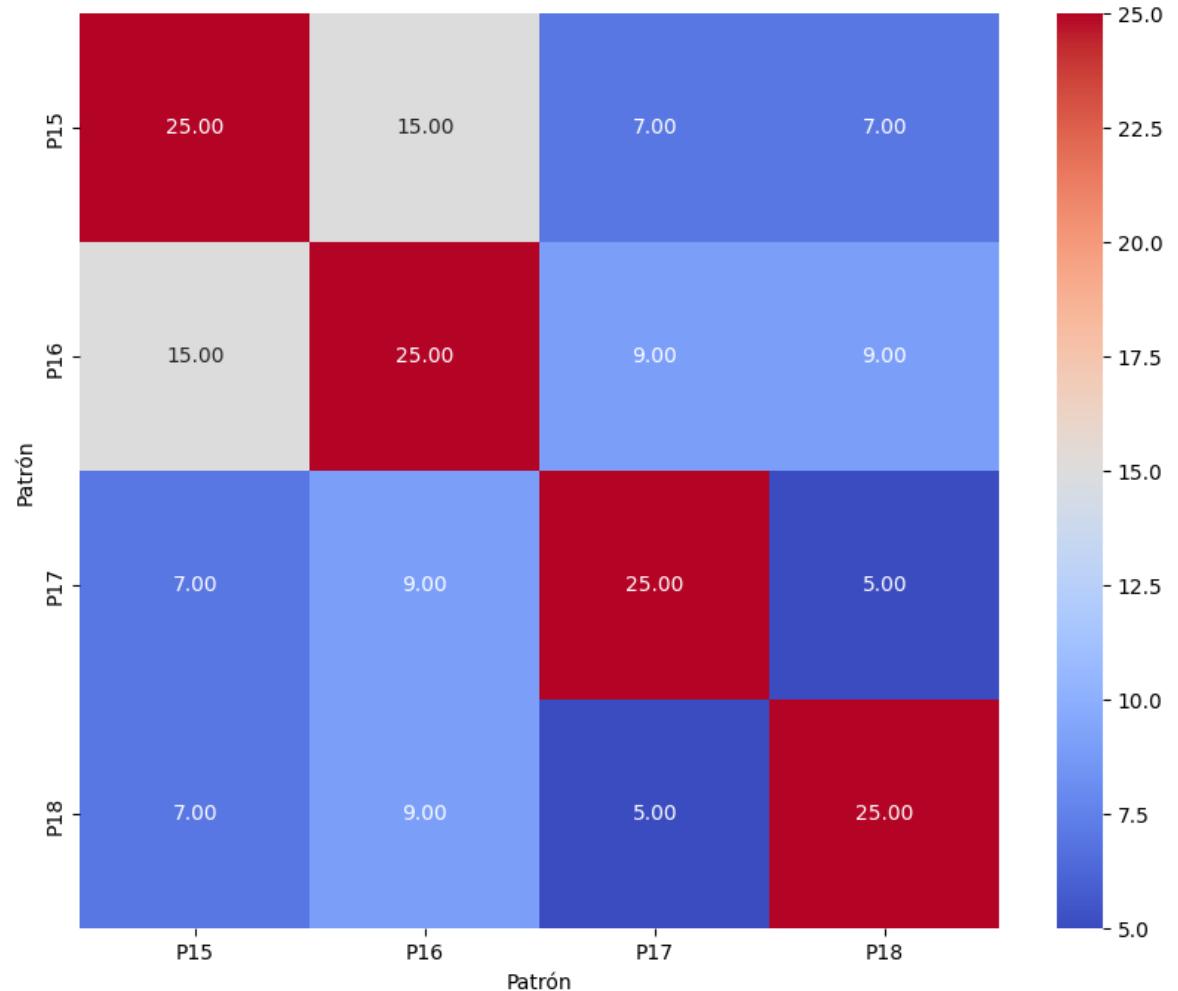
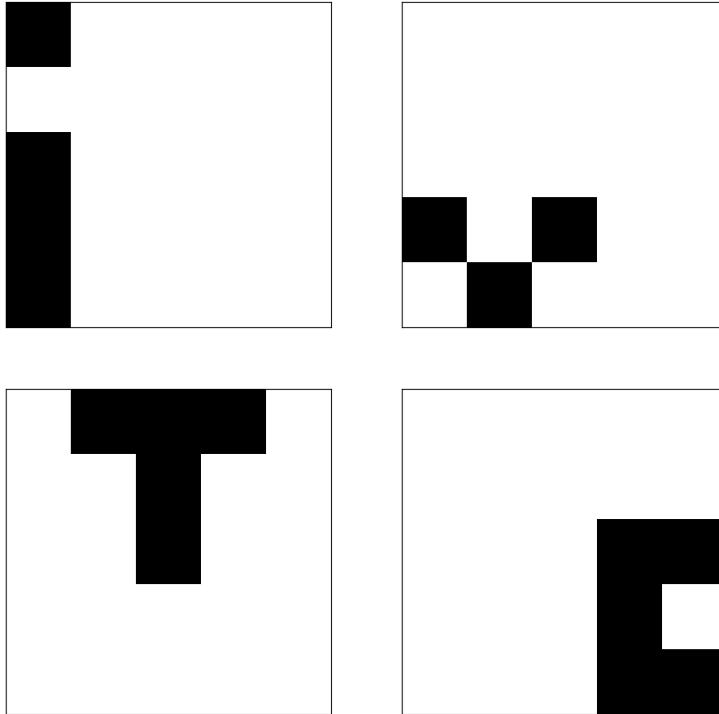


# Análisis de patrones ortogonales

## Matriz de producto punto



## Se replantea los patrones



## Se replantea el modelo

### *Modelo de Hopfield*



Pergamon

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0893-6080/97 \$17.00+.00

PII: S0893-6080(97)00026-9

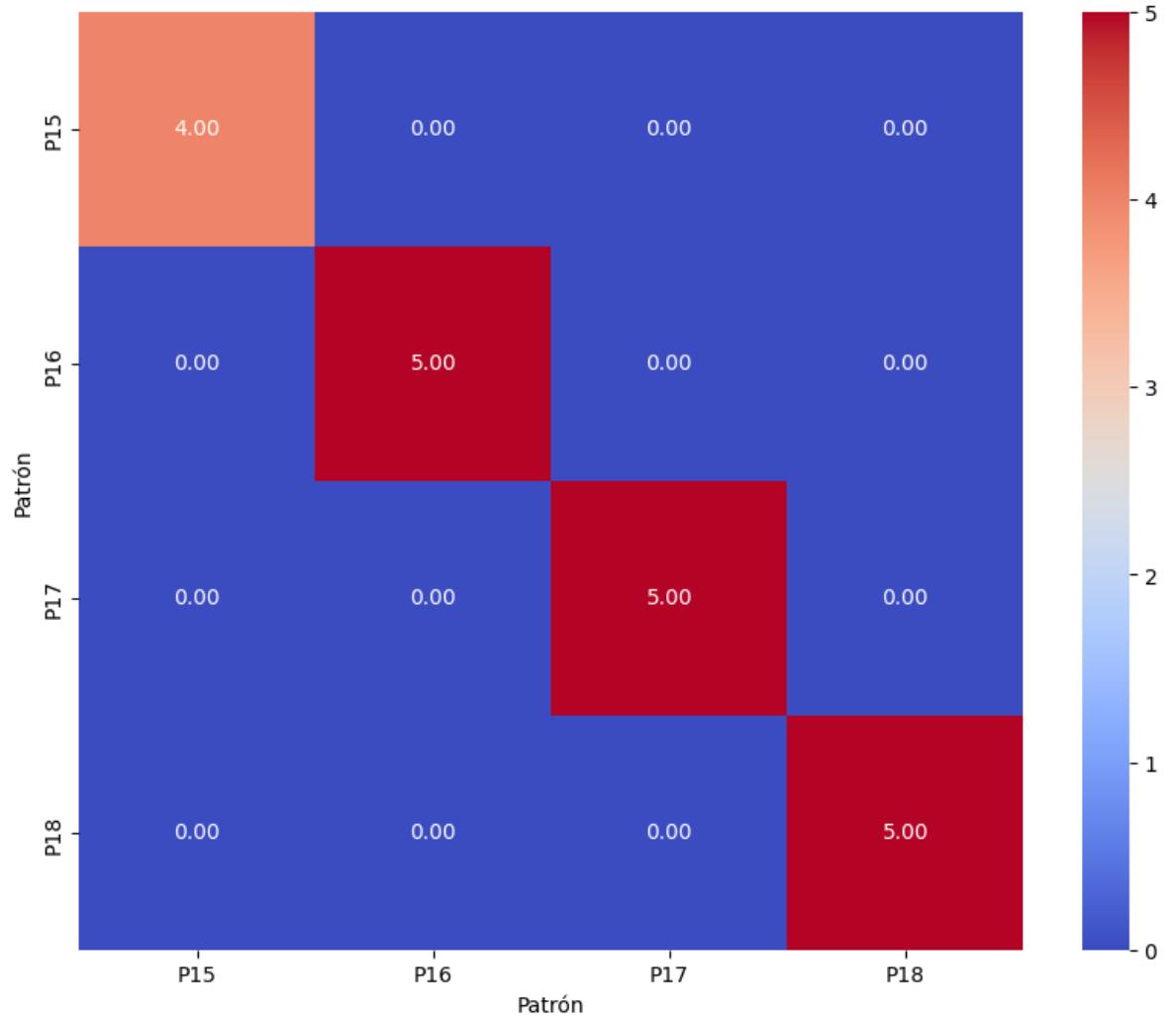
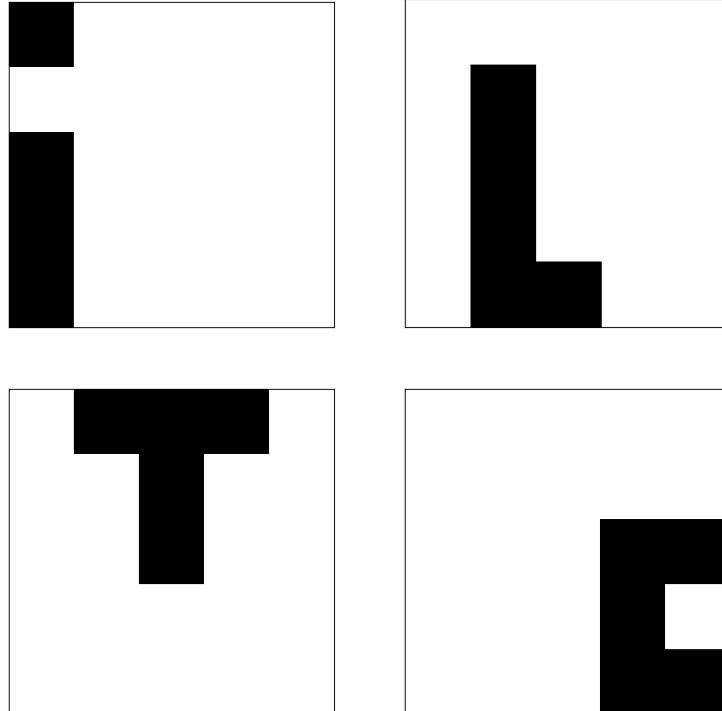
CONTRIBUTED ARTICLE

The Stability of the Generalized Hopfield Networks in  
Randomly Asynchronous Mode

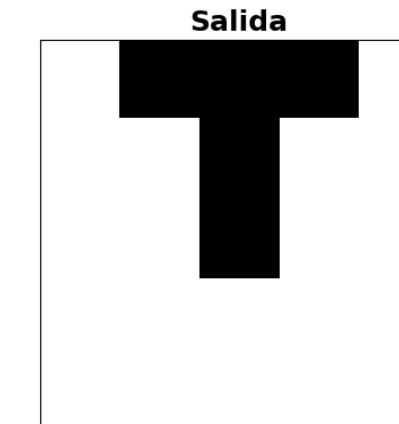
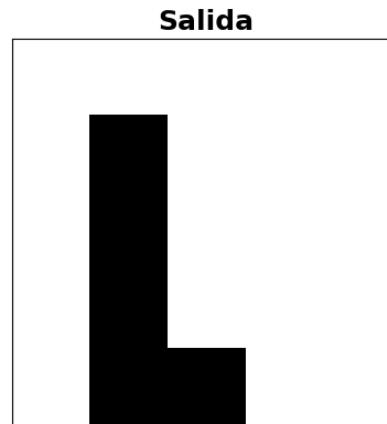
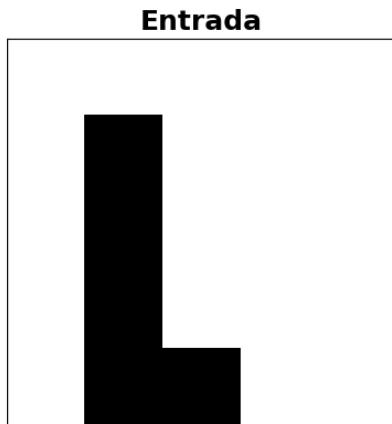
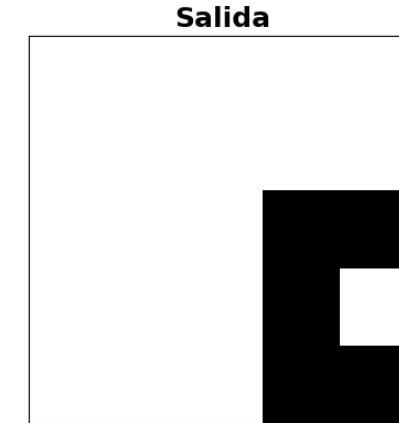
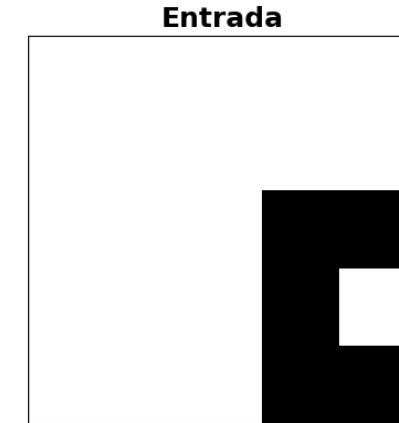
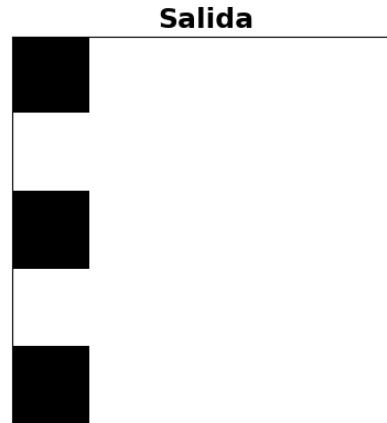
$$a_i = \begin{cases} 1 & \text{si } \sum_j w_{ij} s_j \geq 0 \\ 0 & \text{si } \sum_j w_{ij} s_j < 0 \end{cases}$$

$$F_i(X) = I(H_i(X)) = \begin{cases} 1 & \text{if } H_i(X) \geq 0 \\ 0 & \text{otherwise} \end{cases}$$

## Se replantea los patrones

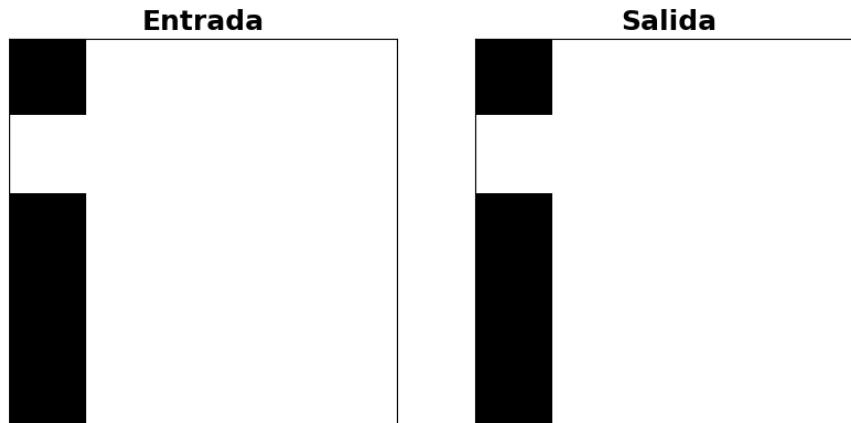
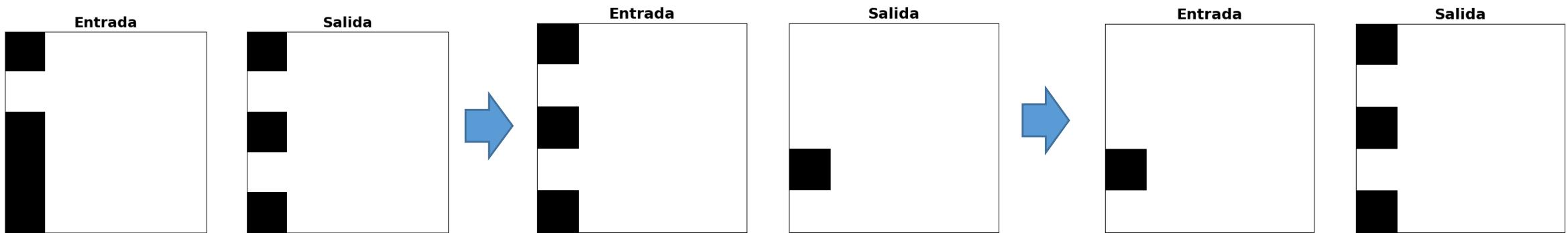


## Se replantea los patrones



## Se replantea los patrones

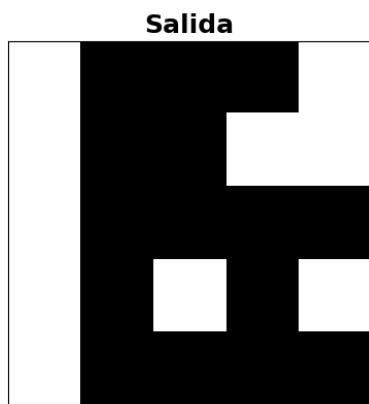
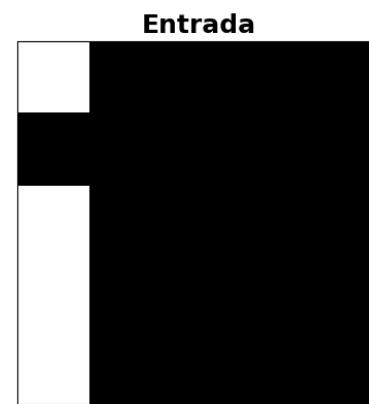
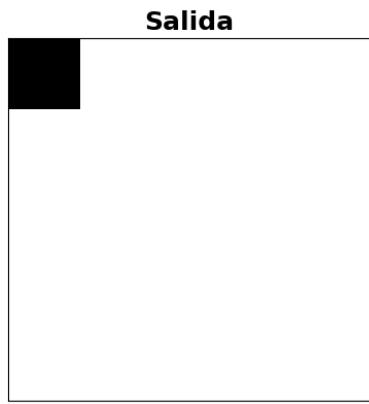
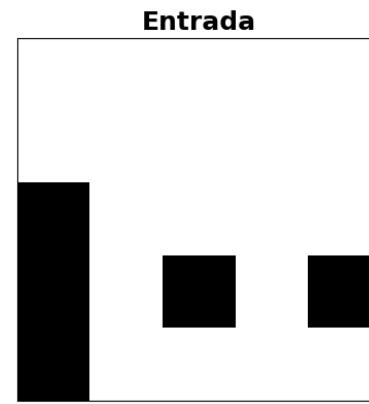
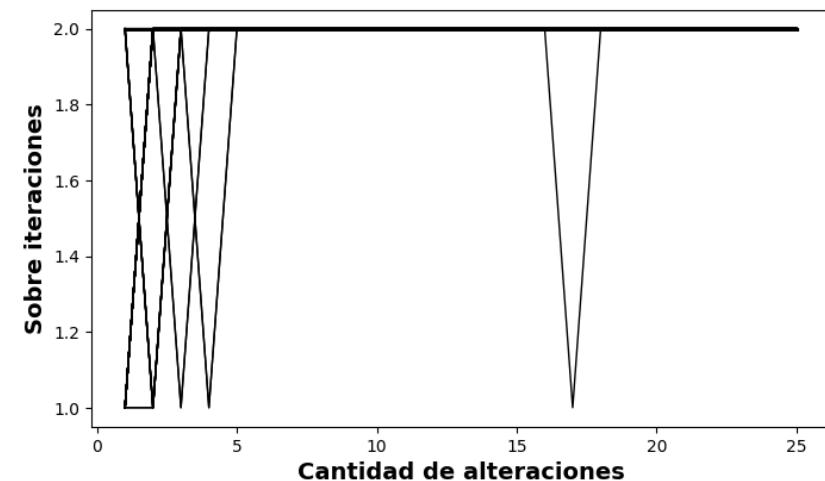
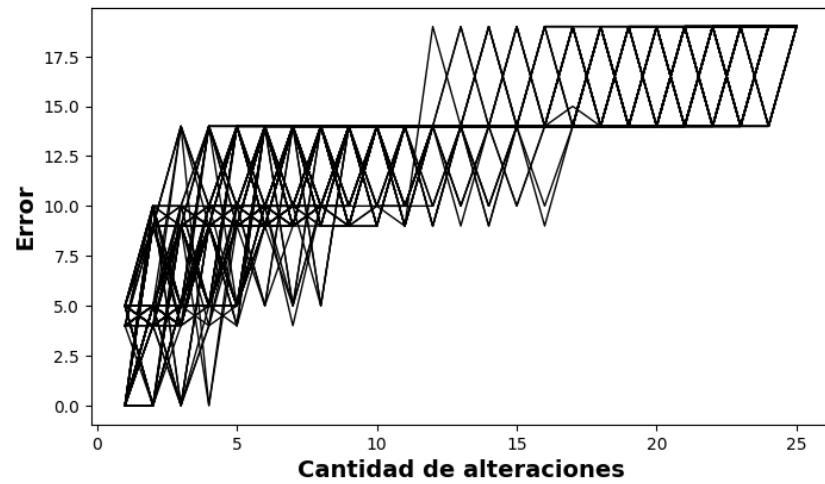
$$w_{ij} = \frac{1}{N} \sum_{\mu=1}^p \xi_i^\mu \xi_j^\mu$$



$$w_{ij} = \frac{1}{10} \sum_{\mu=1}^p \xi_i^\mu \xi_j^\mu$$

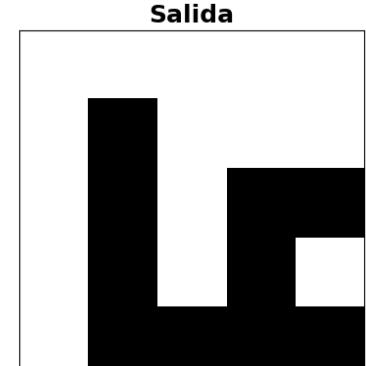
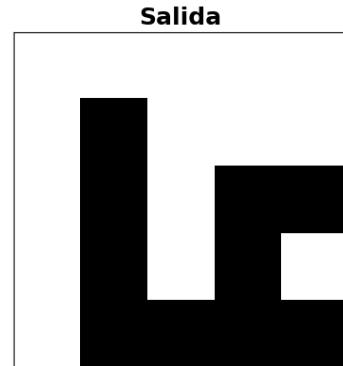
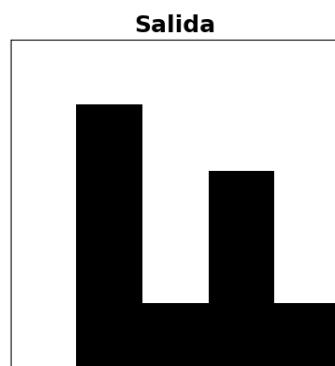
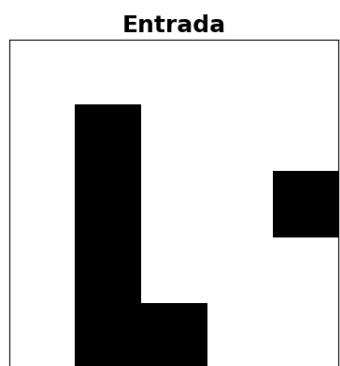
Solo cumple para 10

## Desempeño del modelo



## Energía

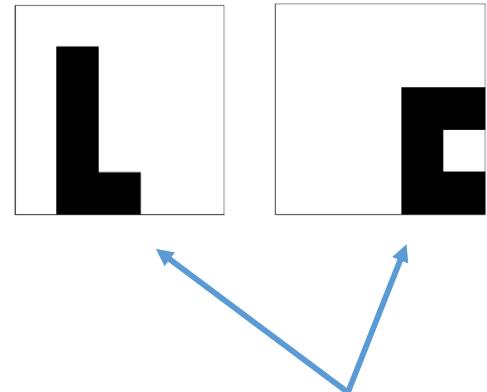
$$E = -\frac{1}{2} \sum_{i,j} w_{ij} s_i s_j$$



Energía entrada: -0.04000000000000002  
Energía salida: -0.10000000000000005  
Delta: -0.0600000000000026

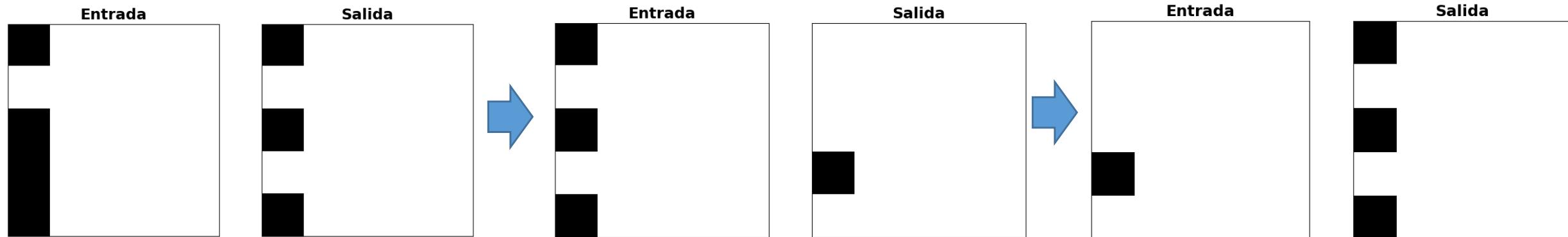
Energía entrada: -0.10000000000000005  
Energía salida: -0.20000000000000004  
Delta: -0.0999999999999999

Energía entrada: -0.20000000000000004  
Energía salida: -0.20000000000000004  
Delta: 0.0



## Energía

$$E = -\frac{1}{2} \sum_{i,j} w_{ij} s_i s_j$$

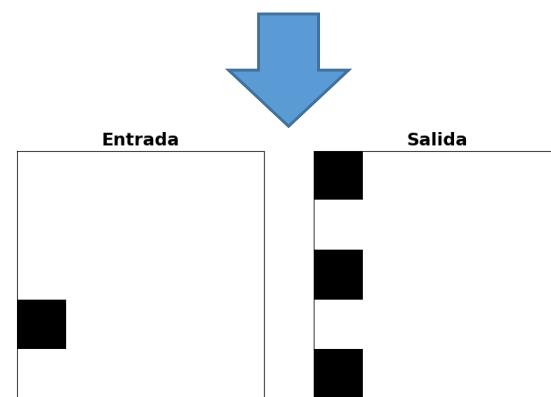
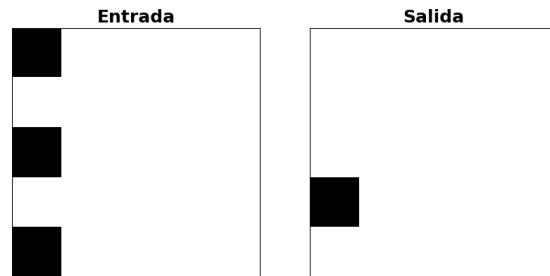


Energía entrada: -2.42861286636753e-17  
Energía salida: 0.059999999999999984  
Delta: 0.06000000000000001

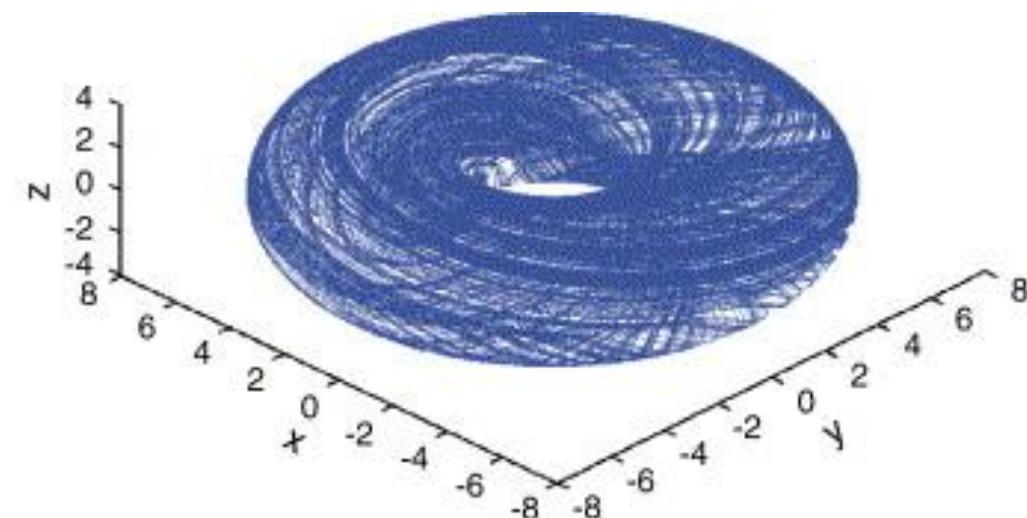
Energía entrada: 0.059999999999999984  
Energía salida: 0.06  
Delta: 1.3877787807814457e-17

Energía entrada: 0.06  
Energía salida: 0.059999999999999984  
Delta: -1.3877787807814457e-17

## Energía



$$E = -\frac{1}{2} \sum_{i,j} w_{ij} s_i s_j$$



Gracias por la  
atención