FÍSICA COMPUTACIONAL

MODELO DE ISING CUÁNTICO UNIDIMENSIONAL EN UNA GRILLA DE N ESPINES: ANÁLISIS ESPECTRAL

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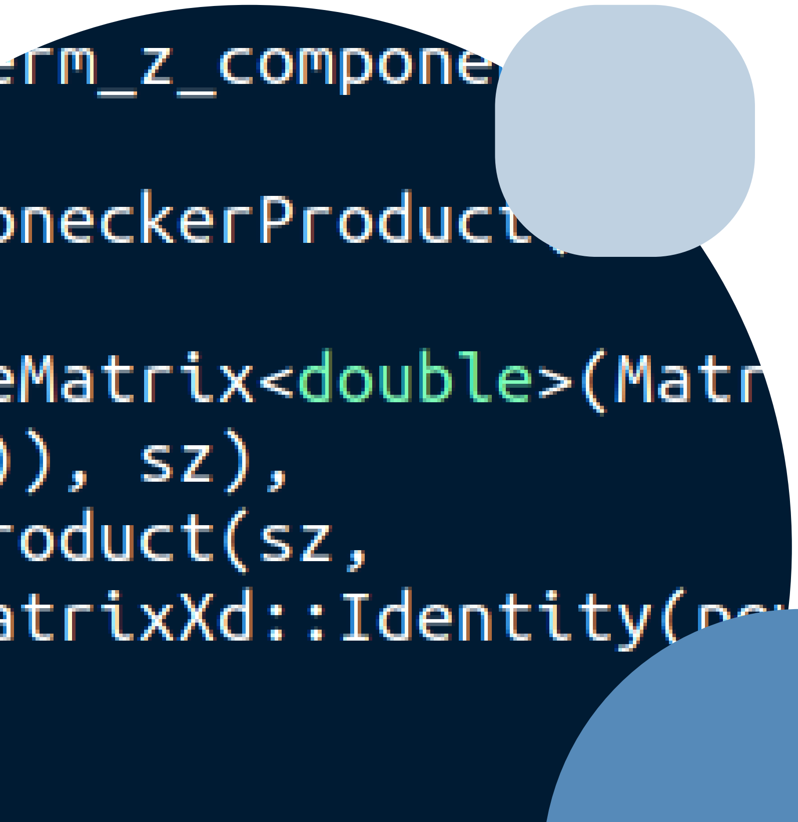


CONTENIDOS

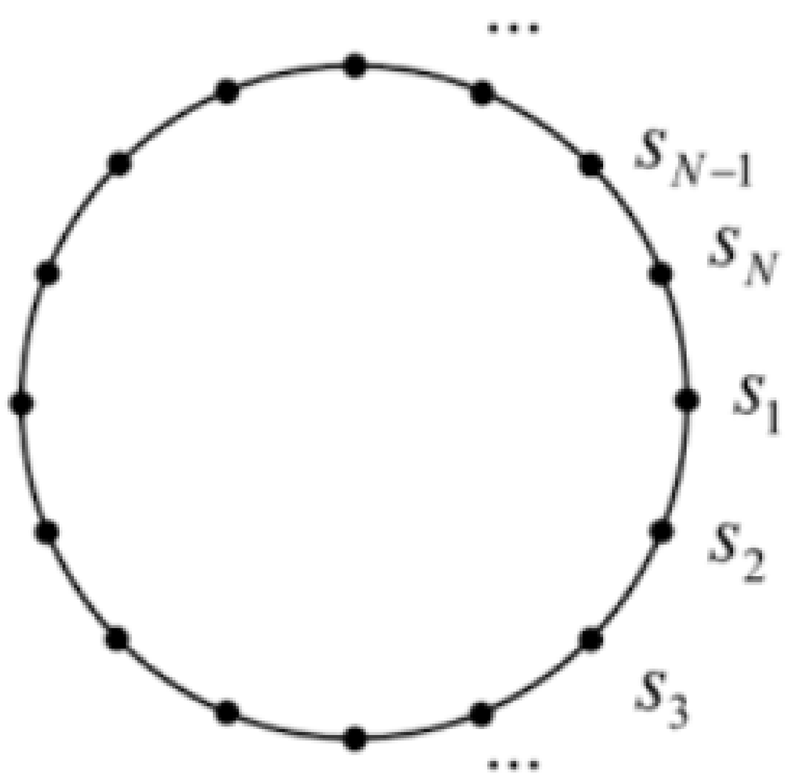
CONTEXTO

(csc_matrix(
= term_z
ino de campo transversal
= - g * kron(
on(eye(2**i, dtype=np.fl
(2**(N-i-1), dtype=np.

MODELO DE ISING CUÁNTICO UNIDIMENSIONAL

PARÁMETROS

J: Escala energética que determina interacción ferromagnética
g: Parámetro energético de campo transversal
Se trabaja con matrices de Pauli



HAMILTONIANO

Describe la energía total de un sistema físico en términos por ejemplo de sus momentos y coordenadas.

$$\hat{H} = -J\sum_{i=1}^{N}\hat{\sigma}_i^z\hat{\sigma}_{i+1}^z - g\sum_{i=1}^{N}\hat{\sigma}_i^x$$

$$\hat{H} = -J \sum_{i=1}^{N} \hat{\sigma}_i^z \hat{\sigma}_{i+1}^z - g \sum_{i=1}^{N} \hat{\sigma}_i^x$$

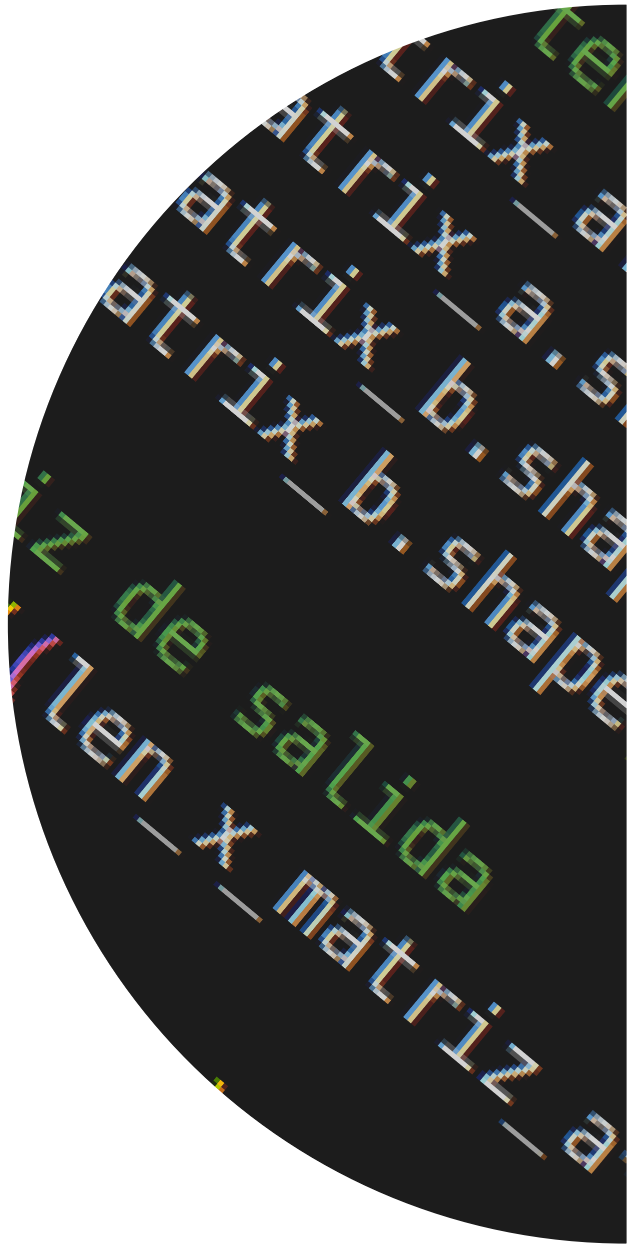
$$\hat{\sigma}_1^z = \hat{\sigma}^z \otimes \mathbb{1} \qquad \hat{\sigma}_2^z = \mathbb{1} \otimes \hat{\sigma}^z \qquad \hat{\sigma}_1^x = \hat{\sigma}^x \otimes \mathbb{1} \qquad \hat{\sigma}_2^x = \mathbb{1} \otimes \hat{\sigma}^x$$

$$\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \otimes \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} = \begin{bmatrix} a_{11} \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} & a_{12} \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} \\ & \\ a_{21} \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} & a_{22} \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} \end{bmatrix}$$

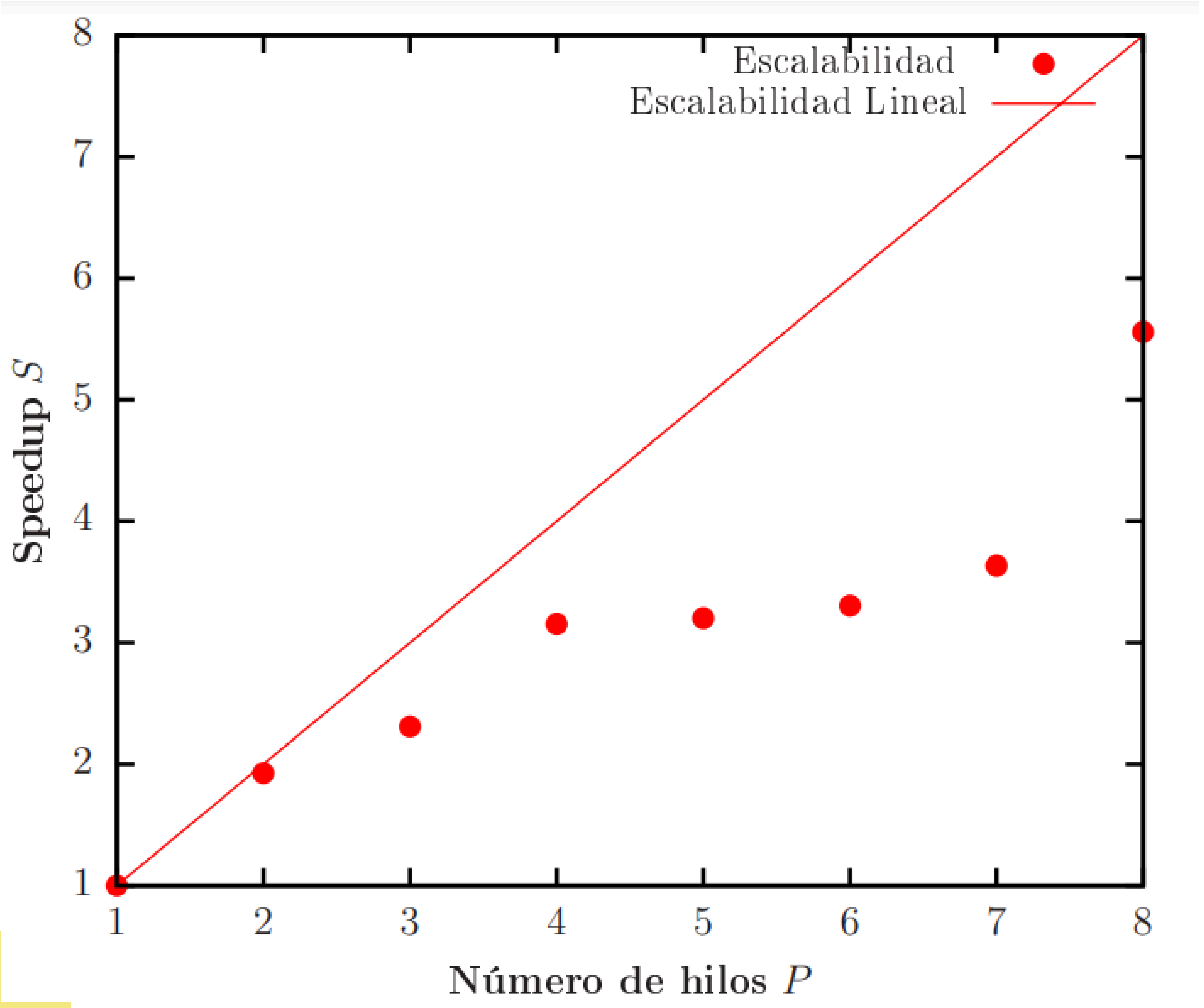
$$= \begin{bmatrix} a_{11}b_{11} & a_{11}b_{12} & a_{12}b_{11} & a_{12}b_{12} \\ a_{11}b_{21} & a_{11}b_{22} & a_{12}b_{21} & a_{12}b_{22} \\ a_{21}b_{11} & a_{21}b_{12} & a_{22}b_{11} & a_{22}b_{12} \\ a_{21}b_{21} & a_{21}b_{22} & a_{22}b_{21} & a_{22}b_{22} \end{bmatrix}$$

PRODUCTOS TENSORIALES

CÓDIGO



- Implementación del hamiltoniano con productos tensoriales.
- Implementación del hamiltoniano sin productos tensoriales.
- Escalar el sistema a N espines.
- Paralelización.
- Diagonalización.


Escalabilidad
Escalabilidad Lineal
Speedup S
Número de hilos P
1
2
3
4
5
6
7
8

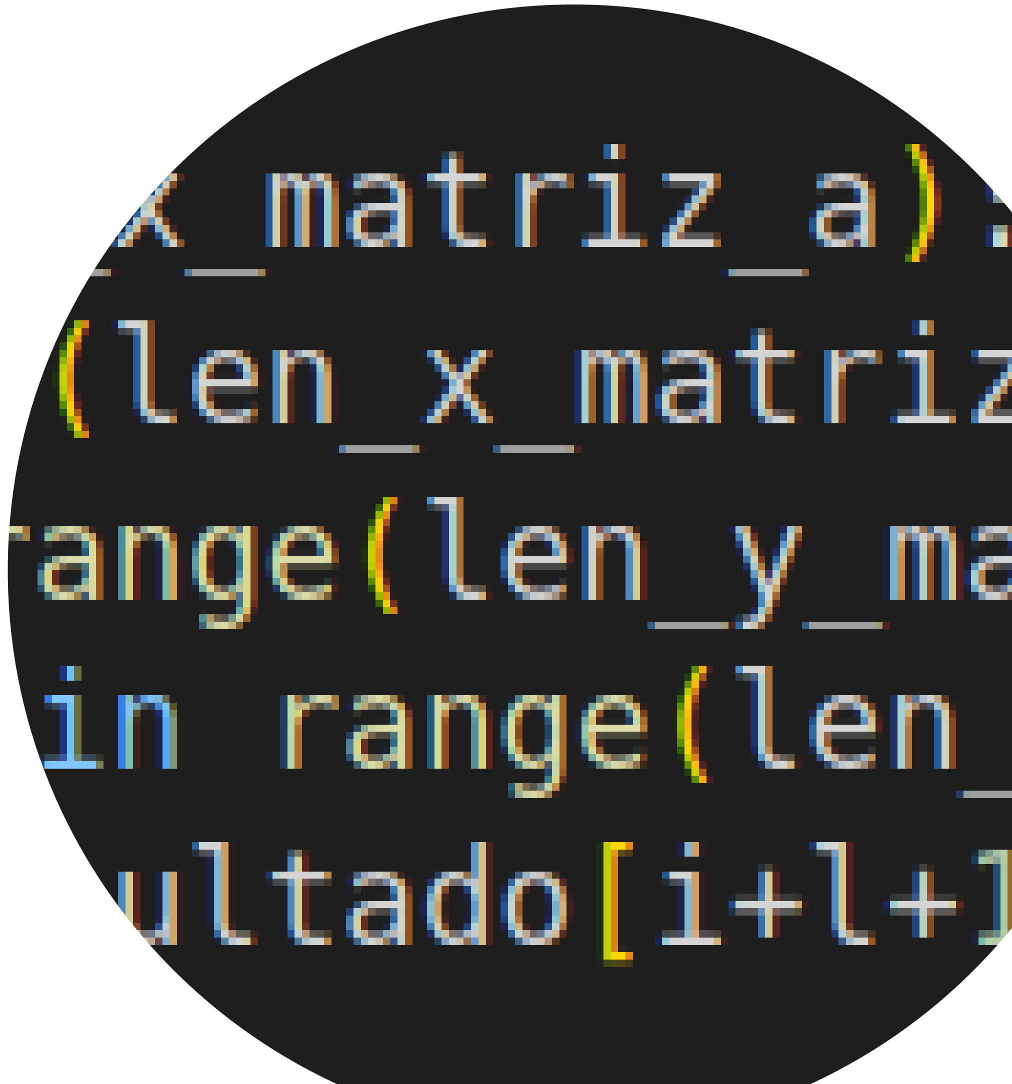
TRANSFORMACIÓN DE JORDAN-WIGNER

$$E_0 = -\frac{1}{2}\sum_{n=-L/2}^{L/2-1} \epsilon\left(k_n\right) \qquad E_0^R = -\frac{1}{2}\sum_{n=-L/2}^{L/2-1} \epsilon\left(p_n\right)$$

$$\epsilon\left(q\right) = 2J\sqrt{1+h^2-2h\cos\left(q\right)}, \qquad k_n = \frac{2\pi\left(n+1/2\right)}{L}, \qquad p_n = \frac{2\pi n}{L}, \qquad n = -\frac{L}{2},\cdots,\frac{L}{2}-1$$

A.H. Kole. Density Matrix Renormalization Group calculations for the Ising Model with a Transverse Field. (2018)

DIFICULTADES



PYTHON

- Sintaxis sencilla
- Lenguaje interpretado: Menor rendimiento.
- La paralelizacion es menos flexible

C++

- Lenguaje compilado: Mayor rendimiento
- Mayor intervención en números complejos
- Sintaxis más compleja
- Control sobre la gestión de memoria

UTILIDAD

- ESTUDIO DE PROPIEDADES TERMODINÁMICAS
- SIMULACIONES NUMÉRICAS
- EJEMPLO PRÁCTICO (FIG 1)

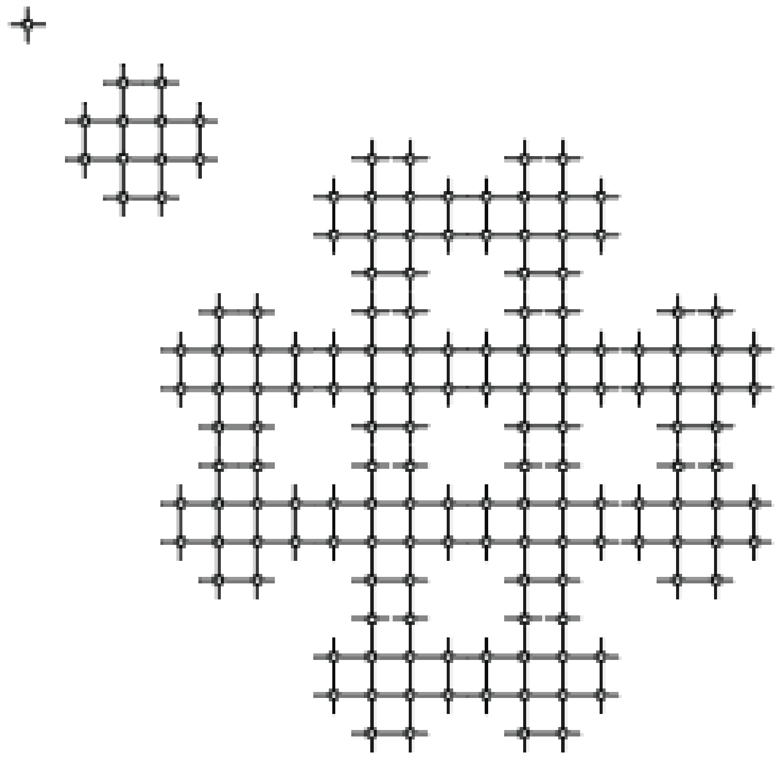


FIG. 1. Composition of the fractal lattice. Upper left: a local vertex around an Ising spin shown by the empty dot. Middle: the basic cluster which contains $N_1 = 12$ vertices. Lower right: the extended cluster which contains $N_2 = 12^2$ vertices. In each step of the system extension, the linear size of the system increases by the factor of 4, where only 12 units are linked, and where 4 units at the corners are missing, if it is compared with a 4 by 4 square cluster.

Jozef Genzor, Andrej Gendiar, and Tomotoshi Nishino, "Phase Transition of the Ising Model on Fractal Lattice," arXiv:1509.05596v2 [cond-mat.stat-mech], 26 Dec 2015.

¡MUCHAS GRACIAS!

REFERENCIAS

- Jozef Genzor, Andrej Gendiar, and Tomotoshi Nishino, "Phase Transition of the Ising Model on Fractal Lattice," arXiv:1509.05596v2 [cond-mat.stat-mech], 26 Dec 2015.
- "Ising model on clustered networks: A model for opinion dynamics," Physica A 623 (2023) 128811.