A Simple Computational Model of Information Propagation in 2D Lattice Space

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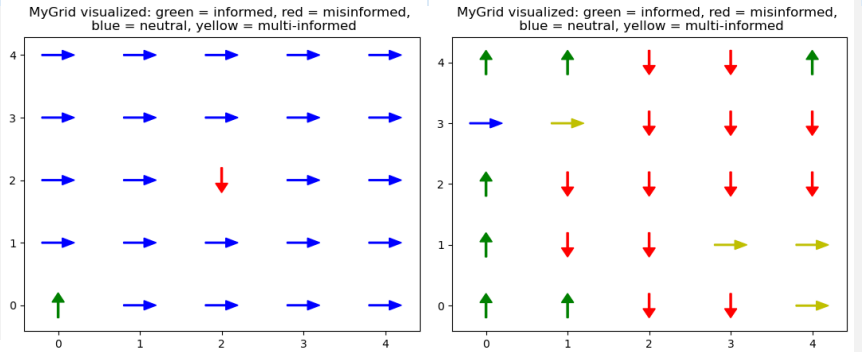
Background

- In the digital era with information explosion, navigating true and false information is challenging
- Inspired by **2D Ising model** [3]: particles in lattice as discrete nodes of propagation, states of particles as status of knowledge of news
- Other existing models of information propagation:
  - Transmission of infectious diseases [1] (SIR model: susceptible-infected-recovered)
  - Control of misinformation on social media

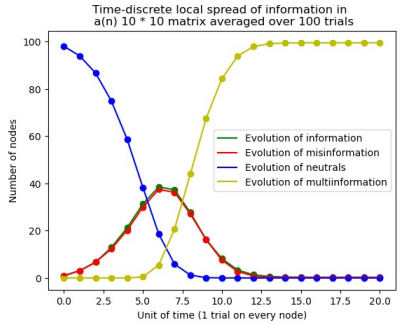
Definitions and Variables

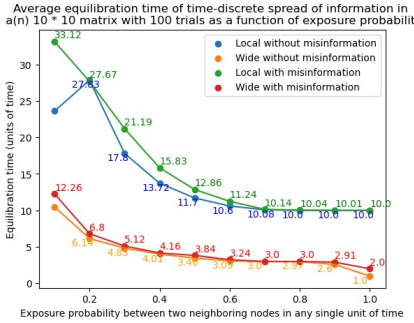
- **News:** a global event that may be represented truthfully or falsely
- **Information:** a particular type of state of any local individual's knowledge of news
  - Neutral or uninformed: "n"
  - Informed: "t"
  - Misinformed: "f"
  - Multi-informed: "m" ("t" + "f")
- **Space:** $N \times M$ 2D rectangular lattice with periodic boundary conditions (mainly 10×10 and 50×50)
- **Time:** $1\ unit\ of\ time\ (uot) = N\times M\ trials$
  - **Time-discrete**: go through every node each *uot*, value updated at end of *uot*
  - Others: real-time update; random order
- **Source(s):** any node that is not neutral at $t = 0$
- **Propagation:** neutral nodes become non-neutral based on neighboring node states (**local** / **wide**)
- **Contact / exposure to information:** probabilistic, but guarantees knowledge of that information
  $$P(information) = P(exposure) = \boldsymbol{p}$$
- **Age factor:** based on the SIR model, nodes no longer spread info after $\boldsymbol{a}$ stable units ($a = 5$ for "t" and "f" , $a = 2$ for "m")

Methods and Main Results



Sample (local) propagation in 5×5 grid from $t = 0$ (left) to $t = 10$ (right) ($p = 0.2$)





- Typical evolution with $source\_map = [(0, 0, 't'), (5, 5, 'f')]$, $p = 0.5$
- Similar patterns in 50×50 grid (graphs not shown here)

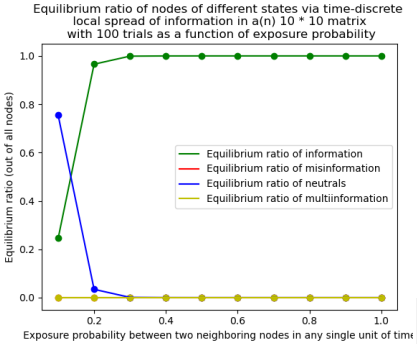
Equilibration time $T(p)$ is similar between different initial conditions but much shorter for wide propagation.

<u>Mechanism of propagation</u>

- For any trial on a neutral node:

$$P(t|n) = (1-(1-p)^t)(1-p)^{f+m}$$
$$P(f|n) = (1-(1-p)^f)(1-p)^{t+m}$$
$$P(n|n) = (1-p)^{t+f+m}$$
$$P(m|n) = 1 - P(t) - P(f) - P(n)$$

- **Local:** only by immediate neighbors (4 nearest nodes)
- **Wide:** proximity-based, effective power $= d^{-2}$



Initially single source. When $p \geq 0.2$, the information can almost always reach all nodes.

Discussion and Conclusion

- This model can simulate information propagation in scenarios similar to fixed 2D lattices and verify statistical predictions of when and how **equilibrium** is reached.
- Enabling **contact between far neighbors** significantly speeds up propagation.
- There is a **critical p_0** in whether equilibrium can be reached globally non-trivially for a certain a. For $a = 5$, $p_0 \approx 0.2$.
- These apply to **different grid sizes and initial source conditions**.
- Further consider the effects of the following:
  - Global sources (announcements)
  - Surprisal of misinformation [2], which may produce state-specific p
  - Credulity: a reduced p when exposed but not credulous
  - Individual differences in p
  - Fluidity in node motion

References and Acknowledgment

[1] Jenner, A.L., *et al*. Leveraging Computational Modeling to Understand Infectious Diseases. *Curr Pathobiol Rep* **8**, 149–161 (2020).
[2] https://en.wikipedia.org/wiki/Information_content

- This project is the final project of the course PHYS 25000 taught by Professor David Miller at the University of Chicago in Autumn 2024: [3] https://github.com/UChicagoPhysics/PHYS250/tree/master.
- In particular, the material on Ising model is extensively cited.

- For more visualization results, please scan the QR code to access GitHub repository.