Competition of entries from Ising Wikipedia networks

Leonardo Ermann
GIyA, CNEA Buenos Aires

Klaus M Frahm
LPT UPS CNRS Toulouse

Dima L Shepelyansky
LPT UPS CNRS Toulouse

Introduction

We introduce the Ising Network Opinion Formation (INOF) model for Wikipedia and apply it for the analysis of networks of several Wikipedia language editions of 2017, 2024 and 2025. In the model, Ising spins are placed at directed network nodes/articles and the steady-state opinion polarization of spins is determined from an asynchronous Monte Carlo process in which a given spin orientation is determined by in-going links from other spins (Ermann and Shepelyansky, 2024). We consider competition between such entries as *capitalism, imperialism* (blue opinion) vs. *socialism, communism* (red opinion), *Apple Inc.* (red) vs. *Microsoft* (blue), Vladimir Putin (red) vs. Donald Trump (blue) and others.

Methods

The Wikipedia network of a given edition is obtained from directed citation links between articles/nodes. There are approximately $N \approx 5.4 \times 10^6$ nodes for EN Wiki2017 and 6.8×10^6 for EN Wiki2024 (Frahm and Shepelyansky, 2025). As usual (Ermann et al., 2015) the matrix of Markov transitions between nodes is constructed from an adjacency matrix A_{ij}; thus $S_{ij} = 1/k_{ij}$ where k_{ij} is the number of out-going links from node j to node i; for dangling nodes without out-going links $S_{ij} = 1/N$ and $\sum_i S_{ij} = 1$. As in (Ermann and Shepelyansky, 2024) the selected nodes (wiki-articles) have assigned fixed spin values $\sigma_l = -1$ blue e.g. for *capitalism* and *imperialism* and $\sigma_k = 1$ for *socialism* and *communism*. These specific spin nodes always keep their polarization. All other nodes are assigned a white color (or spin $\sigma = 0$) at the initial stage of the asynchronous Monte Carlo process, we call this a white option. Such a choice of initial state of all spins corresponds to a situation when all other spins, those which are not fixed, have no definite initial opinion. Then we choose a random spin i, which is not fixed, and compute its influence score from in-going links j:

$$Z_i = \sum_{j \neq i} \sigma_j V_{ij}. \qquad (1)$$

where the sum is over all nodes j linking to node i. V_{ij} is the element of the vote matrix, defined by one of two options: $V_{ij} = A_{ij}$ (the adjacency matrix element, option OPA), or $V_{ij} = \tilde{S}_{ij}$ (the modified Markov transition matrix element, option OPS). For the OPS option, the matrix S_{ij} is used, in which columns corresponding to dangling nodes contain only zero elements, ensuring these nodes do not contribute to Z_i. We discuss two options OPA and OPS with a primary focus on the OPA case. $\sigma_j = 1$ if the spin of node j is oriented up, or $\sigma_j = -1$ if it is oriented down, or $\sigma_j = 0$ if the node j has no opinion (if it has still its initial white value). After the computation of quantity Z_i, the spin of node i, σ_i, is updated: it becomes $\sigma_i = 1$ if $Z_i > 0$, $\sigma_i = -1$ if $Z_i < 0$, and remains unchanged if $Z_i = 0$. This operation is repeated for all non-fixed nodes i' following a predetermined random order (shuffle). Here the modified value of σ_i is used for the computation of $Z_{i'}$ of subsequent values $\sigma_{i'}$. One full pass updating all non-fixed spins constitutes a single time step, $\tau = 1$. The procedure is then repeated for subsequent time steps $\tau = 2, 3, \ldots$ using a new random shuffle for the update order at each step. We find that the final steady-state is reached after $\tau \approx 20$ steps. There is a small fraction of nodes that remain white for $\tau \geq 20$ which we attribute to their presence in isolated communities; thus, these nodes are not taken into account when determining the opinion polarization of others. We point out that compared to the usual case of Wikipedia networks the size of the configuration space of the INOF model is drastically increased to 2^N instead of N.

Repeating this asynchronous Monte Carlo process, with different random orders for the spin flip defined by the rule (1), we obtain various random realizations, and leading to different final steady-state distributions in each case. Using this data we perform an average over up to $N_r = 10^5$ pathway realizations that gives us an average opinion polarization μ_i of a given spin (node, article). The averaging over all spins gives the global polarization μ_0 with a deviation $\Delta\mu_i = \mu_i - \mu_0$ for each article. This deviation $\Delta\mu_i$ represents the opinion preference of a given article i to red or blue entries as compared to the average global Wikipedia opinion μ_0.

A similar asynchronous Monte Carlo procedure is used for the problems of associative memory but there $\tilde{S}_{ij}$ in (1) have positive and negative values ± 1 (Hopfield, 1982; Benedetti et al., 2024).

Results

The density distribution of opinion polarization μ_i of Wikipedia articles.nodes is shown in Figure 1. In fact the steady-state distribution of red and blue nodes is mainly concentrated at spin values 0 or 1 with fractions f_r, f_b or red, blue nodes so that $\mu_0 \approx 2f_r - 1$ ($f_r + f_b = 1$). The results for two different slots with $N_r = 10^5$ pathway realizations for each one provide rather close distributions even if certain fluctuations are still visible. The global polarization is $\mu_0 \approx 0.146$ showing the clear preference of Wikipedia articles for *socialism, communism*.

The INOF method allows to obtain opinion polarization of all Wikipedia articles with respect to selected fixed red and blue entries. Thus in Figure 2, we show the opinion polarization for world countries. The strongest preference for *socialism, communism* is found in Europe and Russia which is clearly related to the initial historical development of these concepts there.

In Figure 3, we present the opinion polarization of world countries with respect to two companies *Microsoft* (blue $\mu = -1$) vs. *Apple Inc.* (red $\mu = 1$) for Ising Wikipedia EN of October 2024. The opinion polarization, averaged over all $N \approx 6.8 \times 10^6$ and all $N_r = 10^5$ pathway realizations, is $\mu_0 = 0.053$ being in favor of Apple Inc.. The top countries with highest preference $\Delta\mu > 0$ for Apple Inc. are *Ireland, India, United Arab Emirates, Australia, New Zealand* and those with preference $\Delta\mu < 0$ for Microsoft are *Russia, Moldova, Iraq, Azerbaijan, Bosnia and Herzegovina*. USA has a very slight preference for *Apple Inc.* and China very slight one for *Microsoft*. A significant preference of India for *Apple Inc.* is related to the presence of several direct links pointing from Apple-related articles to India.

In Table 1, we present values of the opinion preference expressed by $\Delta\mu$ in favor of *Apple Inc.* or *Microsoft*. for people from internet and computer science, certain politicians and leading world trillion-dollar companies. We find naturally preference of Steve Jobs, Steve Wozniak for *Apple Inc.* and Bill Gates, Paul Allen for *Microsoft*.

In the same Table 1, we present results for the competition of *Elon Musk* (red $\mu = 1$) vs. *Mark Zuckerberg* (blue $\mu = -1$) obtained for EN Wiki2024. The global Wikipedia network preference in strongly in favor of *Elon Musk* with $\mu_0 = 0.468$. For the article listed in Table 1 almost for all of them the preference is also in favor of *Elon Musk* even if Meta Platforms have a higher capitalization as compared to Tesla, Inc. We attribute this to a very diverse activities of *Elon Musk* including Tesla, Inc., SpaceX, X etc comparing to activities of *Mark Zuckerberg*.

Thus the INOF analysis of Ising Wikipedia networks allows to obtain varieties of opinions for competing entries from Wikipedia. More detailed description of the INOF approach and its applications is available at (Ermann and Shepelyansky, 2024; Frahm et al., 2024; Frahm et al., 2025).

Discussion

The described INOF approach is generic and can be applied to various directed networks. Thus in (Frahm et al., 2024) this approach allowed to describe myocardial fibrosis progression in the MetaCore network of protein-protein interactions. A variation of this approach (without white nodes) determines dominant features of trade currencies in the World Trade Network from the UN COMTRADE database (Coquide et al., 2023).

Of course, the Wikipedia networks have important exceptional features comparing to other networks: the meaning of their nodes is very clear, they enclose all aspects of nature and human activity and the presence of multiple language editions allows to analyze various cultural views of humanity. Thus we hope that the INOF approach to Ising Wikipedia networks will find diversity of applications.

References

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Article	$\Delta\mu$ (Apple,Micr.)	$\Delta\mu$ (Musk,Zucker.)
Elon Musk	0.0003	$\mu = 1$
Mark Zuckerberg	0.0014	$\mu = -1$
Bill Gates	-0.0013	0.0152
Paul Allen	-0.0007	0.0115
Steve Jobs	0.0063	0.0059
Steve Wozniak	0.0025	0.0122
Sergey Brin	-0.0030	0.0200
Larry Page	-0.0033	0.0203
Vladimir Putin	-0.0015	0.0264
Donald Trump	-0.0005	0.0086
Xi Jinping	0.0000	0.0244
Boris Johnson	0.0060	0.0176
Emmanuel Macron	0.0002	0.0237
Olaf Scholz	-0.0005	0.0253
Giorgia Meloni	0.0001	0.0242
Recep Tayyip Erdoğan	-0.0016	0.0267
Apple Inc.	$\mu = 1$	-0.0007
Microsoft Inc.	$\mu = -1$	0.0181
Nvidia	-0.0127	0.0191
Saudi Aramco	-0.0018	0.0257
Alphabet Inc.	-0.0022	0.0174
Amazon (company)	0.0336	-0.0229
Meta Platforms	-0.0024	0.0165
PetroChina	-0.0002	0.0255
Tesla, Inc.	-0.0025	0.0225
Broadcom	-0.0114	0.0213
TSMC	-0.0061	0.0214
Berkshire Hathaway	0.0034	0.0046

Table 1: Examples of opinion polarization or preference, expressed by $\Delta\mu$ (following OPA), for important personalities from technological companies (top), politicians (middle) and world-leading companies (bottom). Center column corresponds to $\Delta\mu$ for *Apple Inc. vs. Microsoft* ($\mu_0 = 0.053$) confrontation, while right column shows the case for *Elon Musk vs. Mark Zuckerberg* ($\mu_0 = 0.468$).

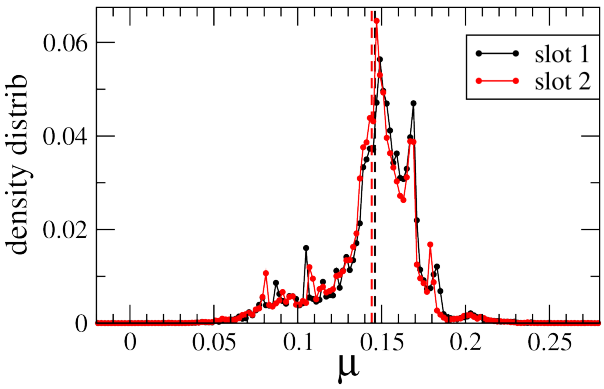

Figure 1: Density distribution of opinion polarization μ for *socialism, communism* and *capitalism, imperialism* obtained for two slots of $N_r = 10^5$ pathway realizations folowing OPA; average polarization μ_0 is marked by dashed lines (EN Wiki2017) (Ermann and Shepelyansky, 2024).

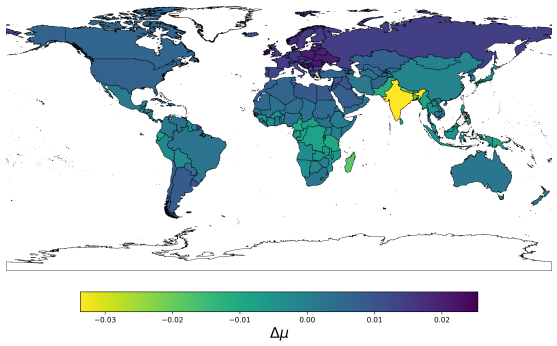

Figure 2: Opinion polarization of world countries for *socialism, communism* ($\Delta\mu > 0$) vs. *capitalism, imperialism* ($\Delta\mu < 0$), $\mu_0 = 0.146$ following OPA (EN Wiki2017) (Ermann and Shepelyansky, 2024).

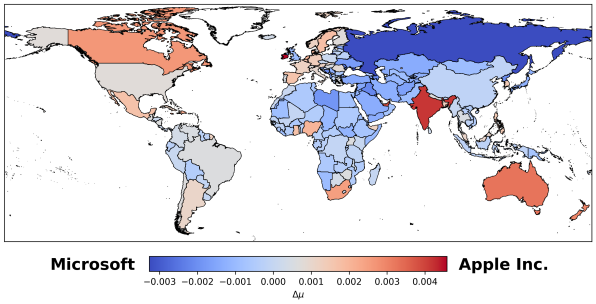

Figure 3: Opinion polarization of world countries for *Apple Inc.* ($\Delta\mu > 0$) vs. *Microsoft* ($\Delta\mu < 0$), $\mu_0 = 0.053$ from EN Wiki2024 following OPA.