UNIVERSITÀ DELLA CALABRIA

AI & Data Science Lab
@DIMES Dept.
MACHINES, LANGUAGES & NETWORKS team

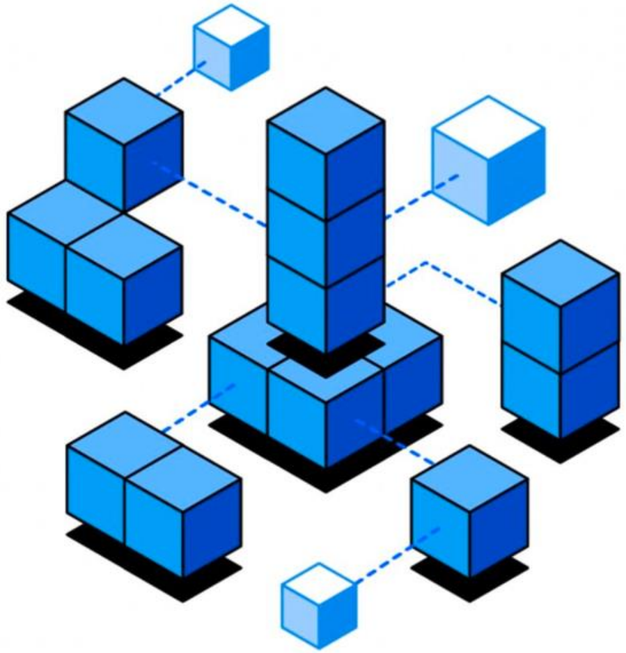
The 16th ACM Web Science Conference 2024
May 21-24, 2024 - Stuttgart, Germany

Polarization in Decentralized Online Social Networks

Lucio La Cava, Domenico Mandaglio, Andrea Tagarelli

DIMES Dept., University of Calabria, Italy

Decentralized Online Social Networks



Source: blueskyweb.xyz

User-Centric

Foster spontaneous and unbiased interactions, advertisement free

Decentralized Growth

Independent yet cooperating servers to escape from individual owners

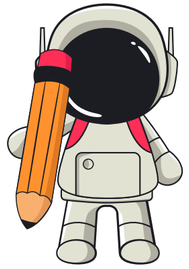
How is decentralization achieved?

Open Source Software

Allows anyone to create a new server, or instance, thus favoring the emergence of communities guided by spontaneous interest towards certain topics

Communication Protocols

Enable seamless communication between (users registered on) different instances, even if pertaining to heterogeneous services



Development of the **Fediverse**
the federated universe of decentralized instances

Here comes Mastodon

- Decentralized alternative to Twitter
- Niche communities and content moderation (cf. Reddit)
- Content policies/rules
- Fine-grained instance controls

Interactions within DOSNs instances

Positive Interactions

Followship relations among people across different servers reflecting on interactions between servers

Negative Interactions

Enforcement of **moderation** policies toward servers (e.g., bans, suspensions, etc)

What are the effects of such interactions?

- Emergence of **polarized** and **conflicting groups**
  - **Intra-group** prevalence of **positive** interactions
  - **Inter-group** prevalence of **negative** interactions
  - High **intra-group density**

Unveiling Polarization in DOSNs instances

(RQ1) *How many polarized groups can be found in Mastodon?*

(RQ2) *What is the polarization structure in Mastodon, that is, how are polarized groups linked internally and to each other?*

(RQ3) *What are the main characteristics of the instances within the detected polarized groups?*

Data Crawling

Detecting positive links among instances

- Seed set of instances from instances.social
- Seed set of **270K Mastodon users**
- *Breadth-first search* to incrementally expand known users
- Identification of **incoming** and **outgoing links**
  - `/api/v1/accounts/:id/followers`
  - `/api/v1/accounts/:id /following`
- **9+ months** of crawling
- **2M users** and **116M unique links** among them

Data Crawling

Detecting negative links among instances

- List of all tracked instances from instances.social
- Crawling of **moderation rules** established from each instance
  - `/api/v1/instance/domain_blocks`
  - **DomainBlocks** JSON objects containing **blocked instances** and **associated metadata** (e.g., the severity and motivation of the block).
- Crawling between July and November 2023
- More than **135K raw enforced blocks** among instances

Network Modeling

Our directed positive instances network

- Nodes represent instances
- Edges represent links between instances deriving from those among users
- Edge weights code the multiplicity of interactions between instances

Our directed negative instances network

- Nodes represent instances
- Edges represent moderation enforced from the source instances to the target ones

$\mathcal{G}^+ = \langle V^+, E^+, w \rangle$ **contains 37,529 nodes and 1,335,490 edges**

$\mathcal{G}^- = \langle V^-, E^- \rangle$ **contains 11,401 nodes and 105,465 edges**

Network Modeling

Simplifying our positive network

- Prune **noisy** of **statistically irrelevant edges** due to spurious interactions
- ***Disparity Filter*** method* to prune edges w.r.t. significance thresholds
  - **117,422** remaining **edges** with $\alpha = 0.05$
- Not needed for the negative network, as blocks among instances are **explicitly declared** by instances' administrators and not due to randomness

Creating our signed instance-network

$$\mathcal{G} = \langle V, E, s \rangle \qquad V \subseteq \mathcal{I},\ E = E^+ \cup E^- \qquad s : E \mapsto \{+1, -1\}$$

$$s(i,j) = +1 \text{ if } (i,j) \in E^+,\ -1 \text{ otherwise}$$

Our resulting network contains 19,738 nodes and 222,887 pos/neg edges

*M. Ángeles Serrano, Marián Boguñá, and Alessandro Vespignani. 2009. Extracting the multiscale backbone of complex weighted networks. Proceedings of the National Academy of Sciences 106, 16 (2009), 6483–6488.

Detecting Polarized Groups

- **Problem:** Given a signed graph G and an integer k, find k mutually-disjoint node sets $\mathcal{P} = \{P_1^*, \cdots, P_k^*\}$ such that:

$$P_1^*, \cdots, P_k^* = \underset{P_1, \cdots, P_k \subseteq V}{\arg\max} \frac{f(P_1, \cdots, P_k)}{\left| \cup_{i=1}^{k} P_i \right|}$$

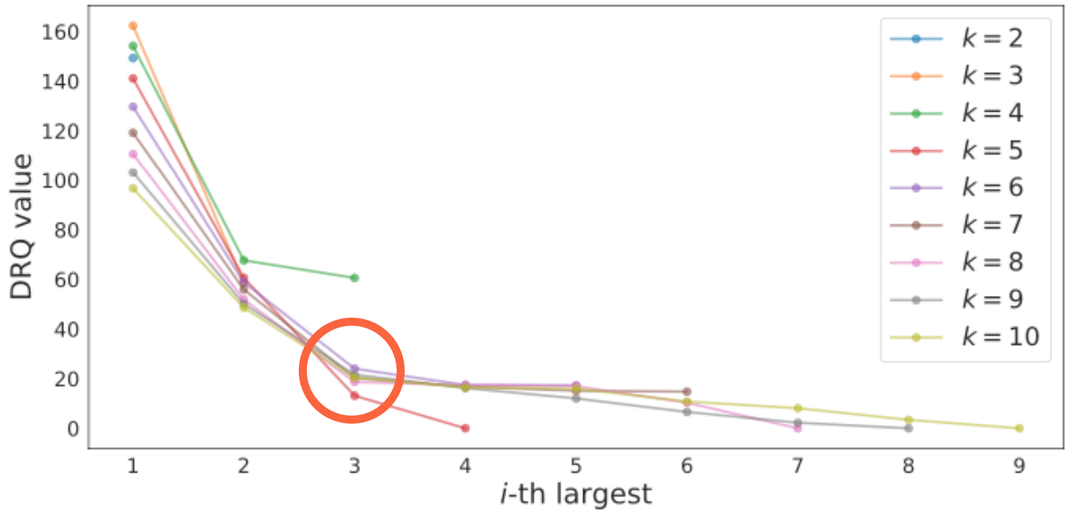
$$f(P_1, \cdots, P_k) = \sum_{P_i \in \mathcal{P}} \left(|E^+(P_i)| - |E^-(P_i)| \right) + \frac{1}{k-1} \sum_{P_i, P_j \in \mathcal{P}} \left(|E^-(P_i, P_j)| - |E^+(P_i, P_j)| \right).$$

- **Spectral Conflicting Groups (SCG)** algorithm
  - Only method admitting *neutral nodes*
  - For each group, it solves **Discrete Rayleigh Quotient (DRQ) problem**
  - The solution to the i-th DRQ problem characterizes the group Pi that conflicts the most with the remaining groups Pj , for $j > i$
  - **DRQ value** representing the **intensity** of such a conflict

*Ruo-Chun Tzeng, Bruno Ordozgoiti, and Aristides Gionis. 2020. Discovering conflicting groups in signed networks. Proc. NIPS Conf. 33 (2020), 10974–10985.

Determining the number of polarized groups

- **Elbow**-like approach
  - Run of SCG with different k values
  - Plotting DRQ values in ascending order, i.e., the i-th largest DRQ value is at the i-th position
  - Determining k to be one of the discernible “knees” on the resulting curve
- $k = 4$ **conflicting groups** with an empty group



3 polarized groups + **1 neutral** group

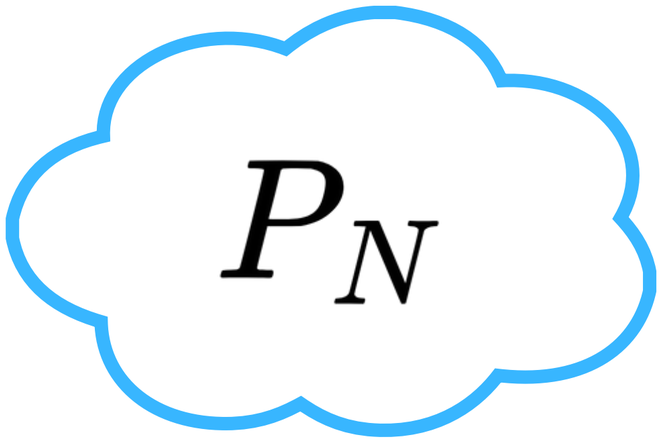
Characterizing polarized groups

- 97% instances in the **neutral group PN** matching the idea of Fediverse
- P1 and P3 are **Mastodon-pure** polarized groups
- **Non-Mastodon** instances dominating the neutral group and P2

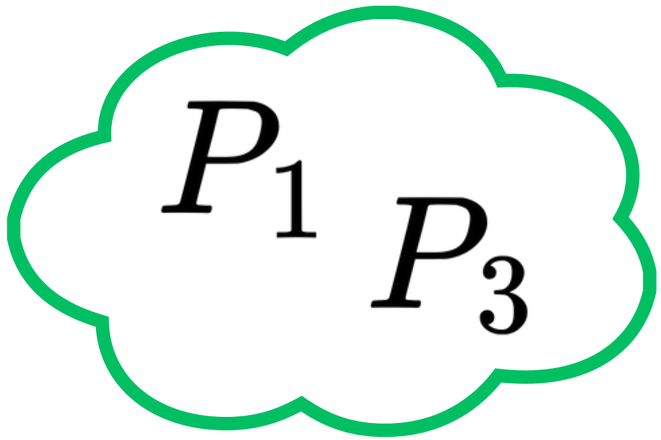
	P_N	P_1	P_2	P_3
# Instances	19,241	189	122	186
% Mastodon	43.6	92.6	36.1	91.4
# Incoming bans	79,690	728	24,651	396
Avg. # bans	12.94	7.35	202.06	7.62
% Instances $\geq$ 1 ban	32.0	52.4	100	28.0

- **PN** and **P2** are the **most banned** within the Fediverse
- **P2** exhibits **higher** (more than 16x) **avg #bans** with **100% instances** receiving at least **one ban**, thus becoming the **“ban-sink”** pole of the Fediverse

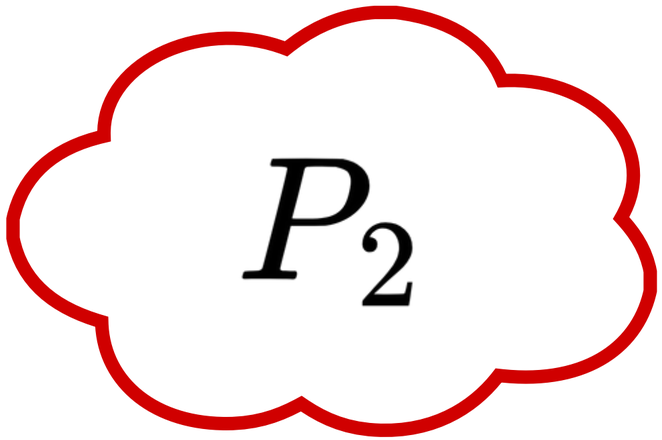
Characterizing polarized groups



Neutral Group

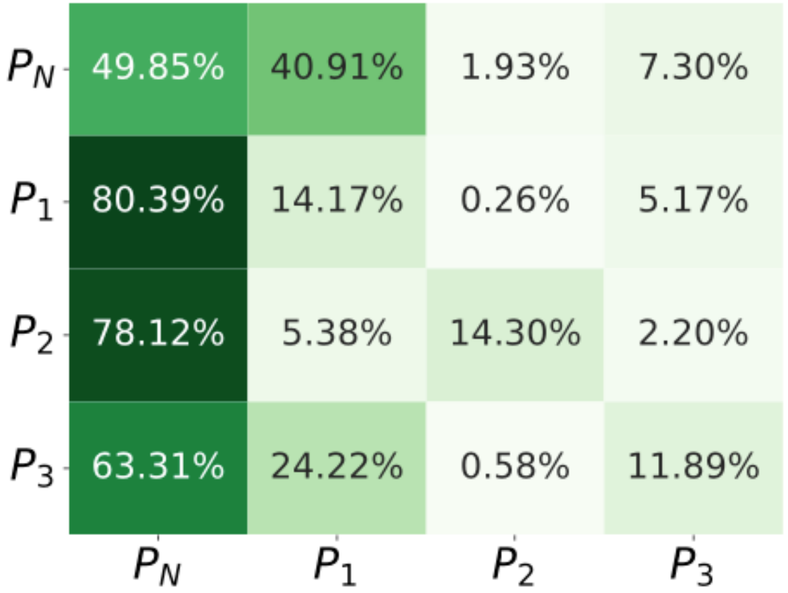


Mastodon-pure Group

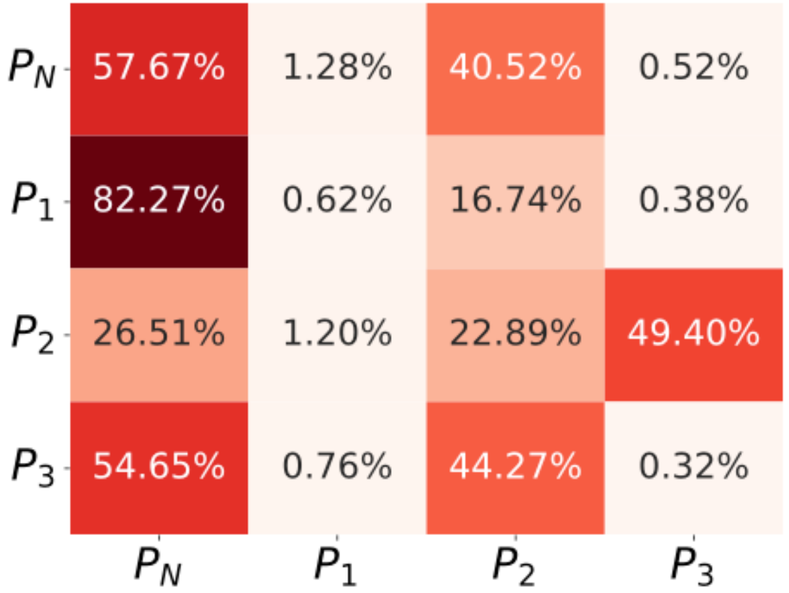


Ban-sink Group

Relations between polarized groups



- Most interactions involve **PN**
- Ban-sink **P2** receiving only interactions from itself, **is it segregation?**



- **Bipartite** banning involving **PN** and **P2**
- Further hints at a **P2 segregation**
- Anomalous bannings from P2 to P3 deserving more attention

Main instances in polarized groups

- ***mstdn.jp*** is among the oldest Mastodon instances and the second-largest Japanese one
- ***mastodon.social*** is the official instance of the Mastodon project
- ***botsin.space*** is the reference instance for running bots on Mastodon

	Most interacted	Most banned
P_N	mstdn.jp	geofront.rocks
P_1	mastodon.social	botsin.space
P_2	pawoo.net	poa.st
P_3	det.social	aethy.com

- ***pawoo.net*** is the second-largest Mastodon instance in terms of users, recently under the spotlight due to the hosting of controversial content
- ***poa.st*** is a *non-Mastodon* instance advertising itself as the "*Fediverse for shitposters*" *

*Source: https://globalextremism.org/post/poast/

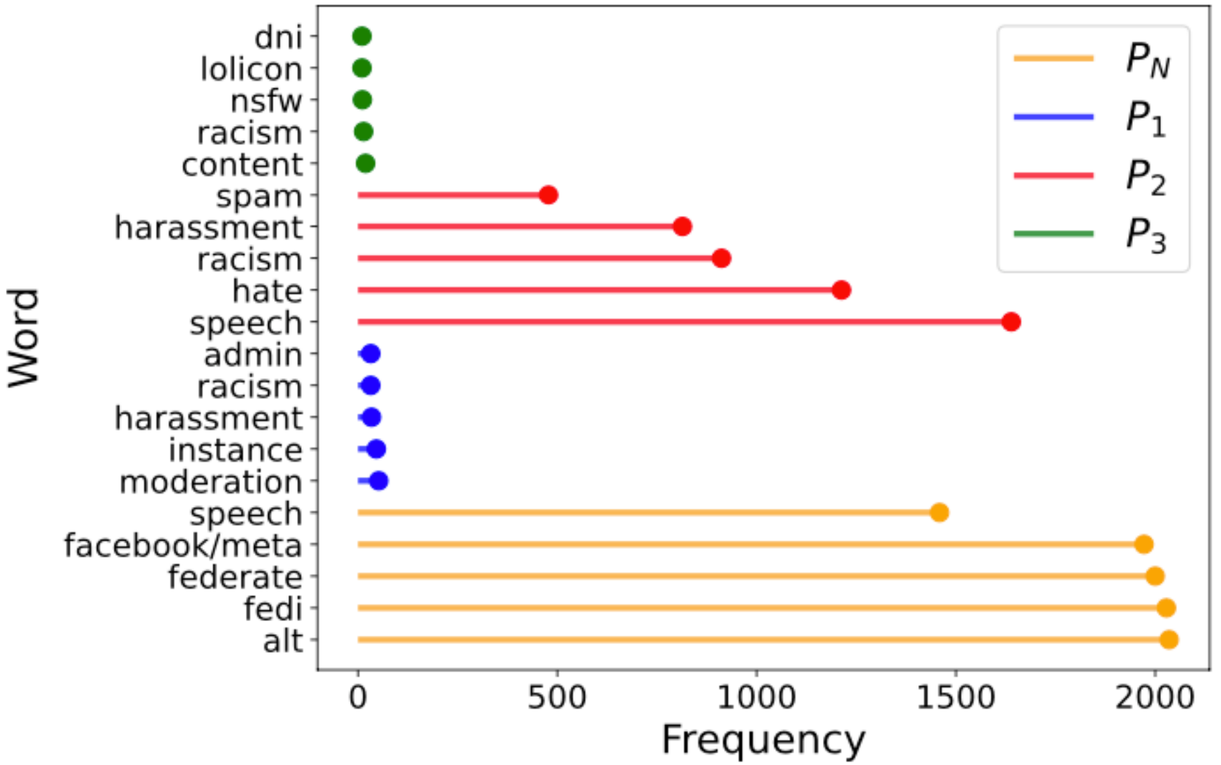
Activity in polarized groups

	Volume	Avg	Top-active Instance	% Volume
P_N	2.37×10^7	3,654	`mstdn.jp`	7.65%
P_1	2.36×10^7	139,511	`mastodon.social`	32.84%
P_2	1.74×10^6	158,065	`pawoo.net`	54.55%
P_3	2.38×10^6	14,356	`mstdn.ca`	15.19%

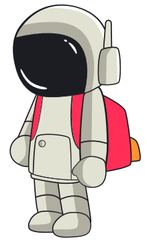
- Collecting, for each pole, the **number of statuses** created in the last **12 weeks**
  - `/api/v1/instance/activity`
- All groups producing **large** volumes of data, especially **PN** and **P1**
- Tail of **small** instances in PN (small avg number of posts)
- **P1** emerging as the **“beating core”** of the Fediverse
  - High avg number of posts and % volume
- **Anomalous volume** in **P2**, considering the concerns about *pawoo.net*

Banning reasons in polarized groups

- No particularly evident motivations in P1 and P3 bannings
- Banning motivations for P2 hint at the ***negativity*** of the group
- PN witnesses bannings due to the moderation of instances that **federate** with **unwelcome** ones (e.g., **Threads**)



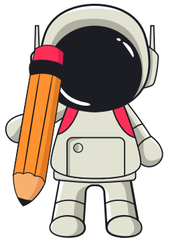
Take Home Messages



(RQ1) *The Mastodon-centric Fediverse instance network encompasses four non-overlapping groups of instances identified as poles*

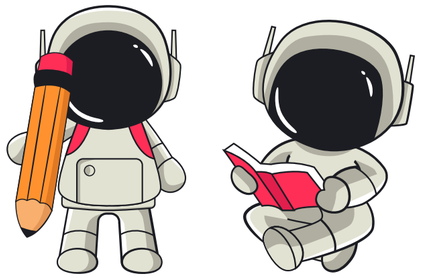
(RQ2) *There is a unique polarization structure with a predominant neutral group, the remainder includes Mastodon-pure groups and a "ban-sink" one, which receives negative links as a protective measure*

(RQ3) *The ban-sink group exhibits anomalous trends in content production, receiving strong moderation due to harmful and inappropriate content*



Future Work: Characterizing *user-level* polarization in DOSNs, also considering *fairness* aspects

Our Mastodon Research Works



La Cava, L., Mandaglio, D., & Tagarelli, A. (2024). *Polarization in Decentralized Online Social Networks.* ACM WebSci'24.

Bono, C.A., La Cava, L., Luceri, L. & Pierri, F. (2024), ***An Exploration of Decentralized Moderation on Mastodon.*** ACM WebSci'24.

La Cava, L., Aiello, L. M., & Tagarelli, A. (2023). ***Drivers of Social Influence in the Twitter migration to Mastodon.*** Scientific Reports, Nature.

La Cava, L., Greco, S., & Tagarelli, A. (2022). ***Information consumption and boundary spanning in Decentralized Online Social Networks: The case of Mastodon users.*** Online Social Networks and Media, Elsevier.

La Cava, L., Greco, S. & Tagarelli, A. ***Understanding the growth of the Fediverse through the lens of Mastodon.*** Applied Network Science, Springer.

La Cava, L., Greco, S., & Tagarelli, A. (2022). ***Network Analysis of the Information Consumption-Production Dichotomy in Mastodon User Behaviors.*** AAAI Conference on Web and Social Media.

La Cava, L., Greco, S. & Tagarelli, A. ***Discovering the Landscape of Decentralized Online Social Networks through Mastodon.*** SEBD 2022.

La Cava L, Ruffo LE, Tagarelli A (2020) ***Towards mesoscopic structural analysis of the Fediverse of decentralized social networks.*** International Conference on Complex Networks and their Applications.

Thanks for your attention!

Interested in knowing more? Contact us!

Lucio La Cava

Assistant Professor

lucio.lacava@dimes.unical.it

Domenico Mandaglio

Assistant Professor

d.mandaglio@dimes.unical.it

Andrea Tagarelli

Associate Professor

andrea.tagarelli@unical.it

UNIVERSITÀ DELLA CALABRIA

Finanziato dall'Unione europea NextGenerationEU

Ministero dell'Università e della Ricerca

Italiadomani

FAIR FUTURE AI RESEARCH