EchoShield: Understanding Structural Hole Spanners to Mitigate Echo Chambers

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Abstract. In the digital world today, online social networks have completely changed how people communicate, form connections, and share information. While social media platforms provide ample opportunities for connections, they can also lead to divisiveness among the users, such as the formation of echo chambers. An *echo chamber* is a virtual environment where a person is only exposed to information and opinions that confirm their existing beliefs. In this initial study, we propose a simulation study that considers different aspects of user profile and user behavior and presence of structural holes to identify the susceptibility and prevention of echo chambers.

Keywords: First keyword · Second keyword · Another keyword.

1 Introduction

With the advent of online social networks, information sharing and communication among users have transformed drastically. While this provides continuous access to information from across the world, it can also lead to opinion segregation among users and formation of echo chambers. For example, existing social media platforms and news media agencies should provide an unbiased view of the news event. However, the continuous competition for user attention and attraction might lead to filtered information that caters specifically to an user. Existing research works [12, 9] define an echo chamber as an isolated virtual room or environment where the users' beliefs and interests are reinforced by repeated exposure to information that aligns with user's specific interests. There are several reasons for creation of an echo chamber, one of which is user's behavior to predominantly seek information which adheres to her/his specific choices and beliefs [13, **?**]. The other reasons include strategic manipulation and selective exposure in information recommendation from platforms coupled with user's confirmation bias [18]. However, this has severe impacts in society, such as, ideological segregation [6] and polarization in society [8, 19].

There are several research works which focus on understanding and identifying echo chambers in different platforms, such as, blogs [10], forums[5] and social media platforms [21]. For example, Cinelli et al. [2] and Wang et al. [20] study the role of homophily in user interactions, cognitive biases and similar political ideology as major factors that leads to echo chambers. Additionally, several research works highlight the significance of social network characteristics, such as, signed networks [7], follower-followee relationships [4], temporal relationships [15], random walks, balance theory [11] and community structure [3, ?], to identify echo chambers. Ge et al. [9] explore formation in echo chambers specifically in e-commerce recommender systems on the basis of variance in user's recommended products on the basis of content diversity. However, these existing recent research works do not provide a unified model that can aid in understanding the formation of echo chamber and highlight mechanisms to prevent it. Additionally, no existing research work highlights difference in echo chamber susceptibility across users on the basis of the high variance across user profiles and their social network connections. Furthermore, there is no echo chamber based study on Indian users.

In order to bridge these gap, we propose a simulation based study with users from India where we consider different types of user profiles, that ranges from different Indian specific political leaning along with user activeness and popularity quotient. We, thereafter study the impact of presence of structural hole, i.e., users with information access from different user groups, in vicinity of users to prevent the formation of echo chambers through temporal opinion dynamics based model. Additionally, we briefly explore the variance of user profiles and their corresponding susceptibility to echo chambers. We showcase our initial study which evidently shows how the presence of structural holes can aid in prevention of ideological segregation and echo chamber formation. The rest of the paper is organized as follows where we discuss details of the proposed approach in Section 2 followed by brief overview of experiments and initial results in Section 3. We finally, conclude in Section 4.

2 Proposed Methodology

In this Section, we initially discuss our dataset details followed by proposed approach.

2.1 Dataset Details

We create a network to mimic the Indian population where we consider several user behavioral traits on social media platforms, such as, information consumption and information production behavior along with user profile [?]. On the basis of each of this, we consider different types of users with different factors as follows, *Political leaning* (Each user is assigned one of three discrete political orientations: government-leaning,opposition-leaning, or neutral), *Production polarity* (represents the bias of the content produced by a user as a continuous value in the range $[0, 1]$, where 0 denotes opposition-leaning content, 1 denotes government-leaning content, and values close to 0.5 represent neutral or balanced content). Similar to *Production polarity*, *Consumption polarity* captures the ideological bias of the information consumed by a user and *User activity coefficient* measures the overall activity level of a user (e.g., higly active, medium active, low active).We follow a power law degree distribution based network where every node is randomly assigned to a political leaning in round robin fashion with respect to degree iteratively till all the nodes are assigned. We formulate an edge between nodes u and v with probability $\Pr(u,v) \propto k_u^{-\gamma} k_v^{-\gamma}$, where γ controls the power-law degree distribution [1].

2.2 Proposed Approach

Through this paper, we investigate the role of structural hole spanners in echo chamber prevention. A structural hole spanner is a node that bridges gaps in a network, enabling information to flow across otherwise disconnected groups [14]. Based on network science theoretic concepts, we propose a combined score of *betweenness centrality*, $BC(v)$ [16] and *bridging social capital score*, $BS(v)$ [1, 17] to identify a node, v as a structural hole spanner. The intuition being that a higher *betweenness centrality* provides a quantitative understanding of the role of the node lying in the most shortest pair wise paths, thereby playing a crucial role in information spread across segregated users, thus aiding in echo chamber formation and mitigation, correspondingly. Furthermore, *bridging social capital score* captures whether a node acts a bridge between segregated parts of the network. Therefore, if a node has either or both high *betweenness centrality*, and *bridging social capital score*, it has high probability to act as a structural hole spanner. Since both metrics might capture complementary aspects (flow control and cross-community bridging), we combine them into a weighted score for user v as,

$$SHS(v) = w \times BC(v) + (1 - w) \times BS(v)$$

The reasoning for threshold decision being that *betweenness centrality* with higher weight as 0.7 because controlling shortest paths is often the strongest indicator of influence in information spreading whereas *bridging social capital score* (weight 0.3) ensures that nodes connecting multiple communities are highlighted, even if their betweenness is not extremely high. Additionally, we empirically investigate the role of both the factors in decreasing echo chamber formation. The opinion evolution in our experiments follows the Friedkin–Johnsen (FJ) opinion dynamics model [22] for structural holes. Each user updates their opinion as a convex combination of their previous opinion and the average opinion of their neighbors, with equal weight assigned to each neighbor. Formally, for a structural hole SH, x_{SH}^t denotes the opinion of structural hole at time t, N_{SH} denotes the set of neighbors of SH and β_{SH} captures individual stubbornness.

$$x_{SH}^{t+1} = \beta_{SH} x_{SH}^t + (1 - \beta_{SH}) \sum_{j \in N_{SH}} w_{SH} x_j^t,$$

where $w_{SH} = \frac{1}{N_{SH}}$ is the weight assigned to each neighbor. We considered equal weight for all the neighbors to ensure diverse information is incorporated from the entire neighborhood which can be further used to maintain balanced

[1] https://en.wikipedia.org/wiki/Power_law

opinions. For regular users, the opinion evolution follows the Friedkin–Johnsen (FJ) model augmented with PageRank-based[2] influence weights and HK-style bounded confidence[3]. Formally, we denote v_r as a regular user, N_r denotes the set of neighbors of regular user, w_{rj} as the influence weight associated with the regular user v_r and its neighbor v_j and β_r captures individual stubbornness of regular user. Let $G = (V, E)$ be an undirected graph with $|V| = N$. The bounded-confidence neighbor set of user v_r at time t is

$$M(v_r, t) = \{v_j \in N_r : \ |x_r^t - x_j^t| \leq \varepsilon\},$$

where $\varepsilon \in [0, 1]$ denotes the bounded-confidence parameter. Each user opinion is only influenced by other users present in the neighbor set. We assign each user a local influence weight w_i using a PageRank-style recursion. The PageRank influence of user v_j is denoted by w_j and is normalized over $M(v_r, t)$ as

$$\bar{w}_{rj}^t = \{ \ w_j \sum_{v_k \in M(v_r,t)} w_k, v_j \in M(v_r, t), 0, otherwise.$$

The FJ opinion update for a regular user v_r is

$$x_r^{t+1} = \beta_r x_r^t + (1 - \beta_r) \sum_{j \in M(v_r,t)} \bar{w}_{rj}^t \, x_j^t,$$

where $\beta_r \in [0, 1]$.

3 Experiments and Results

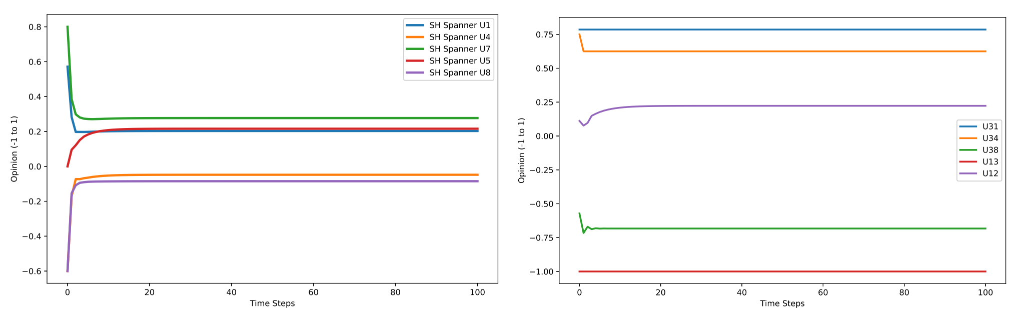
In this Section, we present our initial observations and compare how every user's opinions evolve in the presence of structural hole spanners versus a baseline scenario without the presence of structural hole spanners. Additionally, we intend to understand how the evolution varies across the user related information, such as, their political leaning, activeness and profile related information. This will aid us in understanding opinion evolution and identify the factors and quantitative evidence that these bridging individuals are a significant force for de-polarization.

3.1 Understanding Opinion Evolution

Through this experiment, we intend to understand and visualize the evolution of an users opinion across time and further, whether being a structural hole spanner, i.e., access to information across different segregated sources has an impact on the opinion evolution of an user. We observe the evolution of an user across 100 time steps as shown in Figure 2 for both regular users and structural hole users (we show the results of randomly selected 5 users for visibility in graph).

[2] https://en.wikipedia.org/wiki/PageRank
[3] https://iopscience.iop.org/article/10.1088/1742-6596/1163/1/012064/pdf

The y-axis represents opinion values from -1 (Opposition) to 1 (Government). Our observations as shown in Figure 1b indicates that the opinions of regular users quickly converge and stabilize into three distinct clusters, indicating a highly polarized network whereas the structural hole (SH) spanners as shown in Figure 1a do not remain static but undergo rapid and sharp shifts especially in the early stages and then, consistently shift towards a more neutral position. Further, our observations as shown in Figure 2a compares the frequency of opinion change for regular users and SH spanners where x-axis shows the magnitude of opinion change and the y-axis shows the number of users. We observe that the majority of regular users experienced a very small opinion change, with the distribution heavily skewed towards the left whereas structural hole spanners' opinions are spread across a wide range of change magnitudes, including some of the largest shifts. Therefore, our observations conclude that while regular users have a higher vulnerability to be in echo chambers, structural hole spanners experience a dynamic shift in their opinions due to the availability of information across sides, thus resulting to the ability to be agents that can prevent echo chamber formation and polarization.

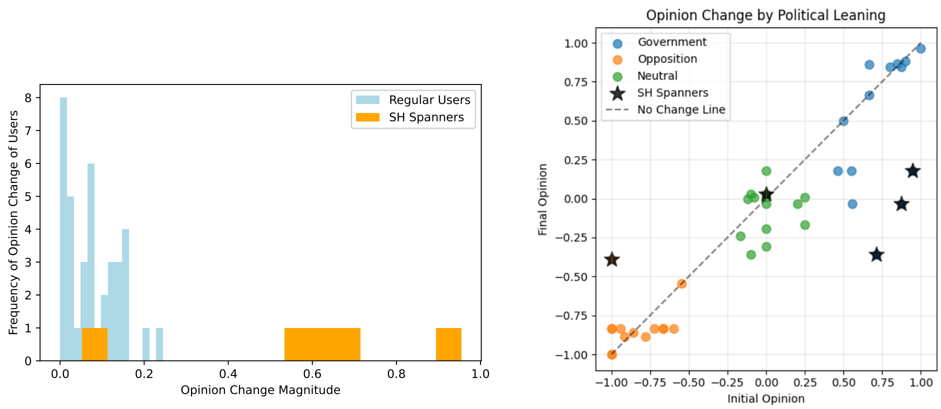


(a) (b)

Fig. 1: Opinion evolution for structural hole and regular users in Figure 1a and Figure 1b

4 Conclusions

With the shift in information consumption, an user has continuous access to information throughout the day and her/his attention shifts on the basis of her/his choice. Therefore, to retain user attention, media platforms provide personalized reading recommendations which might often lead to formation of echo chambers, i.e., an user has access to news that aligns with her/his viewpoint. This has several side effects on society, like segragation among users, polarization, etc. Through this initial study, we simulate opinion dynamics of an Indian user considering different aspects of an user profile along with network structure



(a) (b)

Fig. 2

to understand the role of structural holes to ensure prevention of echo chamber formation.

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