Adaptive Network Approach for Emergence of Societal Bubbles

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Introduction

\begin{itemize}
  \item Social Interactions: An almost unavoidable part of living in a society. It is through social interactions that information spreads.
  \item Complex Networks: Essentially a way of representing and studying systems by breaking them down to components and connections.
  \item Opinion Dynamics: Social interactions are not homogeneous nor static; people tend to have different opinions and also change them depending on the situation.
  \item Consensus or Polarization: When a decision needs to be made, the general wish is to please most of the population either by getting everyone to agree with each other or by ignoring whatever the lesser part of the population wants.
\end{itemize}

Models and Methods

Networks

Consider a social network, where an individual is represented by a node. If two nodes interact then they are connected by an edge. Each node has a degree \( k \), defined by the number of neighbors it has.

Empirical data suggests that most social networks are scale-free having a power-law degree distribution as

\[ P(k) \sim k^{-\gamma} \]

Some other relevant network properties are the clustering coefficient and the average path length, defined as:

\[ C = \frac{2L}{k(k-1)} \quad \text{and} \quad \langle D \rangle = \frac{1}{N(N-1)} \sum D_{ij} \]

Here, \( L \) is the total number of trios formed by \( i \) and two of his neighbors, and \( D_{ij} \) is the smallest number of links between \( i \) and \( j \).

Rules for Changes in Opinion

\begin{itemize}
  \item A network of \( N \) individuals is built. A continuous value \( \delta \) between 0 and 1 is assigned to each node representing their opinion.
  \item For every time step, the individuals verify their neighbors' average opinion \( \langle \delta \rangle = \frac{1}{\sum} \delta(t) \), and computes \( \Delta \delta(t) = \langle \delta \rangle(t) - \delta(t) \).
  \item The new opinion given by \( \delta(t+1) = \delta(t) + \Delta \delta(t) \) if \( \Delta \delta(t) \leq \varepsilon \), and \( \delta(t) = \varepsilon \) if \( \Delta \delta(t) > \varepsilon \).
\end{itemize}

There is a tendency for individuals to approach their opinion to that of his group at a rate \( \mu \geq 0 \) only if it is within a range \( \varepsilon \) of tolerance.

Rules for Changes in Topology

After the opinions \( \delta(t) \) are updated, the connections between \( i \) and his/her \( k \) neighbors can be broken or redirected.

\begin{itemize}
  \item A connection between any pair of nodes \( i \) and \( j \) is kept if \( \Delta \delta(t) = \langle \delta \rangle(t) - \delta(t) \leq \varepsilon \), otherwise, the connection is broken with probability \( p = 1 - \varepsilon^{-k_{ij}} \).
  \item After breaking a connection, a node can create a new one with any other node \( k \) if their opinion differs by less than \( \varepsilon \). The probability is proportional to the distance between them given by:
    \[ q = \varepsilon^{-d_{ij}} \quad \text{if} \quad d_{ij} < d_{\text{max}} \]
    \[ q = 0 \quad \text{otherwise} \]
  \item If a connection is broken but not replaced at a specific time step, it can be replaced at a future time step following the above rules.
\end{itemize}

From the initial state, the opinion distribution changes drastically according to the given value of \( \varepsilon \), resulting in one of the 4 categories \( a, b, c, \) or \( d \) as shown in Figs. 2 and 3.

Due to changes in topology, the network degree distribution deviates from the initial UCM power-law distribution. Due to homophily, individuals tend to form ties with others of the same group, which can be quantified by the average clustering coefficient \( C \).

Conclusions

\begin{itemize}
  \item This approach replicates different sorts of polarization regimes caused only by opinion difference among the nodes.
  \item Through order parameters, transition points between said regimes becomes evident as shown in Fig. 4. Such transition points are backed by other measurements.
  \item Polarized networks show sometimes drastically different properties when compared to regular scale-free unipolarized networks.
\end{itemize}

References


