# Exploring Information Dynamics and Decision-Making Efficiency in Groups: A NetworkX-based Simulation Study of Organizational Structures

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## I. Introduction

In recent years, there has been a growing interest in understanding the effects of organizational structures on information spreading and collective decision-making. Many studies have investigated the impact of different organizational structures on information flow, decision-making efficiency, and the spread of ideas within groups.

Organizational structures are essential to how information spreads and decisions are made within groups. The way individuals and departments are connected, communicate, and collaborate can impact the flow and accuracy of information, as well as the decision-making process. Simulation methods have become a popular tool for investigating the effects of different organizational structures on these phenomena. We examined several studies that have used simulation methods to explore the impact of organizational structures on information spreading and collective decision-making.

One study by Liu and Liu (2021) used a simulation model to investigate the impact of different organizational structures on information diffusion in an online community. They found that network structure, community size, and community cohesion all played a significant role in determining the effectiveness of information diffusion. Another study by Li and Li (2021) used a multi-agent simulation model to examine how organizational structure affects the diffusion of knowledge in an academic organization. They found that centralized structures tended to be more effective in facilitating knowledge diffusion.

In a study by Wang and Li (2019), the authors used an agent-based simulation model to investigate the impact of organizational structure on collective decision-making in a hierarchical organization. They found that decision-making performance improved with more decentralized structures, where decision-making authority was distributed more evenly among individuals.

Similarly, a study by Yang, Zhang, and Cao (2020) used a simulation model to explore the effects of organizational structure on collective decision-making in a multi-agent system. They found that the degree of hierarchy in the organizational structure significantly affected decision-making performance, with more decentralized structures being more effective in facilitating collective decision-making. The gap or question we are addressing in this study is how different organizational structures impact information spreading and collective decision-making in groups. While previous studies have used simulation methods to investigate the effects of organizational structures on these phenomena, there is still a need for further research to fully understand the relationship between organizational structure and information dynamics. Specifically, we aim to investigate how different network structures and decision-making processes impact information diffusion and decision-making efficiency in groups. Simulation methods have proven to be a useful tool to study these phenomena, allowing for the investigation of complex interactions between individuals in organizations. In particular, the use of Python and NetworkX to simulate network structures and analyze their effects has gained popularity. These tools offer flexibility in designing and implementing network models, while providing a comprehensive set of analysis functions.

Previous studies have utilized simulation techniques to investigate the effects of organizational structures on information spreading and decision-making. For example, researchers have used agent-based models to study the role of network structure on information diffusion in social networks. Other studies have explored the impact of hierarchy on decision-making processes in organizations. However, there is still a need for further research on the topic, particularly in exploring the effects of different organizational structures on information spreading and collective decision-making.

This paper addresses the gap in understanding how organizational structures influence information spreading and collective decision-making by employing simulation methods using Python and NetworkX. The simulation is divided into two phases: (1) a fundamental information cascade modeled on a directed Erdős-Rényi graph and (2) a more complex social network simulation with adaptable behaviors and structures based on the Watts-Strogatz model. By structuring the project in these phases, we demonstrate the progression of information spreading from theoretical graph structures to more realistic organizational scenarios.

## II. Information Cascade as the fundamental idea

### A. Method

The phenomenon of information cascades occurs when individuals adopt certain behaviors or beliefs based on the actions or decisions of others, rather than their own independent reasoning or evaluation of the information. Information cascades have been studied extensively in fields such as economics, sociology, and psychology, as they have important implications for decision-making processes and the spread of information in social networks. The problem of information cascade and decision-making based on passed information in organizations is a well-known and widely studied issue in the field of organizational behavior and management.

This phenomenon can be problematic because it can lead to a situation in which the group makes suboptimal decisions based on incomplete or inaccurate information. In the context of organizations, this can have serious consequences for the company's performance and bottom line.

A substantial amount of research has been conducted on information cascades in organizations, with a particular focus on how they arise and how they can be mitigated or prevented. Studies have examined factors such as group size, the degree of uncertainty in the decision-making context, and the extent to which individuals are influenced by social norms and the opinions of others. One that has been proposed to address the problem of information cascades is to encourage greater diversity and independent thinking within the group. This can be achieved through a variety of mechanisms, such as promoting dissenting opinions, assigning devil's advocate roles, and explicitly encouraging individuals to think for themselves.

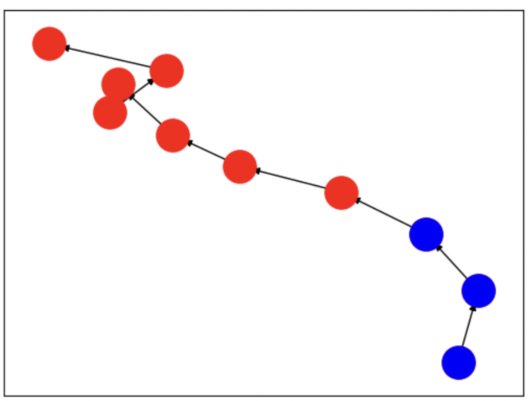

Fig. 1: Basic cascade model

### B. Result

The model simulates a scenario of a popular activity/ behavior in an organization spreading in a random graph. The model uses the NetworkX package to create a directed Erdős-Rényi graph with 50 nodes and a probability of 0.2 for each possible edge. The model considers each node in the graph as an agent that can be influenced by the popular activity.

The model starts by randomly selecting two nodes as the initial nodes that have already adopted the popular activity. The model then adds a node attribute called "activity" to each node in the graph, which indicates whether the node has adopted the behavior or not. All nodes are initialized to False, except for the two start nodes that are set to True.

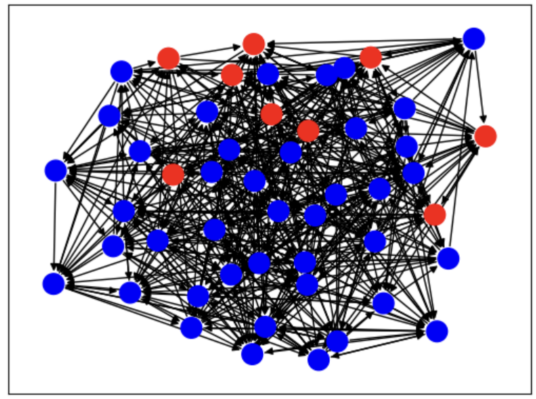

Fig. 2: Erdős-Rényi graph with 50 nodes

The cascade function simulates the spread of the popular activity. The function takes the graph G2, the probability of influence p, and the start nodes as inputs. The function uses two sets to keep track of the nodes that have been influenced and the nodes that are currently active.

The function then enters a loop that continues as long as there are active nodes. In each iteration of the loop, the function removes a node from the active set, selects its neighbors, and attempts to influence each of them. The function checks if the neighbor has already adopted the behavior and if not, generates a random number between 0 and 1. If the random number is less than or equal to p, the function sets the neighbor's activity attribute to True and adds the neighbor to the influenced and active sets. The function continues to iterate over the active set until it is empty, indicating that no more nodes can be influenced. Finally, the model visualizes the results by using the NetworkX package to draw the graph. Each node is represented by a circle, and the nodes that have adopted the behavior are colored red while the others are blue.

## III. Watts-Strogatz model for Social Network

### A. Method

The second part of the project uses the Watts-Strogatz model to simulate the social network. There are three options A, B, and C. Based on the generated graph, we designed three organizational structures: "Democracy", "Aristocracy", and "Tyranny" with corresponding characteristics in Table I.

The agents have properties including whether it is an elite or dictator, personal preference, conversion coefficient (conv), and information processing rate (pr). Each agent also has one information space (shown on the right) to represent its evaluation of all three existing options from three perspectives. At the starting edge, the attribute scores are generated randomly with uniform distribution. The agent will decide its preference by summing up each column and choosing the column with the highest score. In the information spreading stage, it will

| Features | Description |
|---|---|
| **Democracy** | Every agent can spread information and make decisions. When one agent tries to spread information to others sharing the same belief, the information can be spread more efficiently. |
| **Aristocracy** | Every agent can spread information, but only selected elites can make decisions. Elites constitute 20% of the population and are selected at random. Elites have higher information processing rates and conversion coefficients. |
| **Tyranny** | Every agent can spread information, but only the dictator can make decisions. However, if the decision made by the dictator is too unpopular (i.e., differs from 80% of the population), it can potentially be replaced by one of its neighbors. The dictator has the highest information processing rate and conversion coefficient. |

TABLE I: Comparison of governance models

spread one attribute from each of the two options it does not support to its neighbors and two attributes from the supported options. The attribute selection is generated randomly. In the information evaluation stage, each agent adds perceived information to its information space and evaluates the updated columns. If the sum of the new highest column is higher than or equal to the conv*sum of previous preferred options, the agent will update its preference. All direct interactions should occur along edges.

$$x = [x_1, x_2, x_{3,\dots}] \quad x_i \sim Unif\{0,1\}$$

decision options

| attributes | $O_1$ | $O_2$ | $O_3$ |
|---|---|---|---|
| $a_1$ | .41 | .12 | .47 |
| $a_2$ | .25 | .67 | .08 |
| $a_3$ | .29 | .49 | .21 |

Fig. 3: Decision options are generated based on attributes

In summary, the model has two parts of actions: Agent and Team. The information space matrices are central to the final outcomes.

We simulate the behaviors of three organizational structures in networks with different sizes 50, 80, and 100. We analyzed the following performances:

- the change of supporting rates of three options
- the comparison between elite decisions and population decisions

### B. Result

Firstly, as shown in Fig. 5, we can see that the consensus is achieved earlier and the deviation degree decreases in all three structures when N increases. Horizontally, we can find that Democracy brings an earlier and higher degree of dispersion among three decision groups. In addition, one interesting phenomenon we discovered is that the advantaged option gradually lost its dominance and was replaced by another option in some cases. The issue of when and why this phenomenon occurs might be an interesting topic for further research.

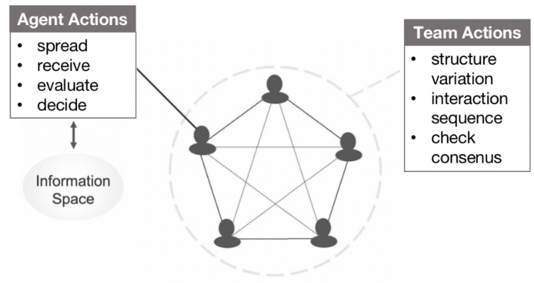


Fig. 4: An overview of the decision-making space

Secondly, for the Aristocracy structure in particular (Fig. 6), we compared the dynamic changes of elite decisions and the population decisions. Similar to the result in the first part, the consensus among elites was also achieved earlier as N increases. In addition, we can find that the consensus and dominance changes among elite groups precede the dispersion among the population. There exists three possibilities: the elites are more sensitive to dynamic changes, the decision of the elites dominates the overall decision, and the combination of both. To figure this question out, we might could add more intermediate variables and investigate the mediation effects in the future.

## IV. Discussion

Our simulation study explored the effects of different organizational structures on information spreading and collective decision-making in groups using Python and NetworkX. Our results suggest that both network structure and decision-making processes play a significant/ moderate significant/weak role in determining the effectiveness of information diffusion and decision-making efficiency.

Our results add to the existing literature on the importance of organizational structures in information dynamics and decision-making processes. They also suggest that simulation methods can be a valuable tool for investigating the effects of different organizational structures on group behavior.

One potential limitation of our study is that it relied on certain assumptions about the behavior of individuals and groups in organizational settings. Specifically, we did not determine our parameters based on literature review. To address these limitations and potential bugs, future work could involve further refining the model and incorporating additional factors that may impact group behavior. This could include adding more complexity to decision-making processes or incorporating cultural and power dynamics into the model. Future studies could also validate and verify the model using real-world data to improve the accuracy of the simulation.

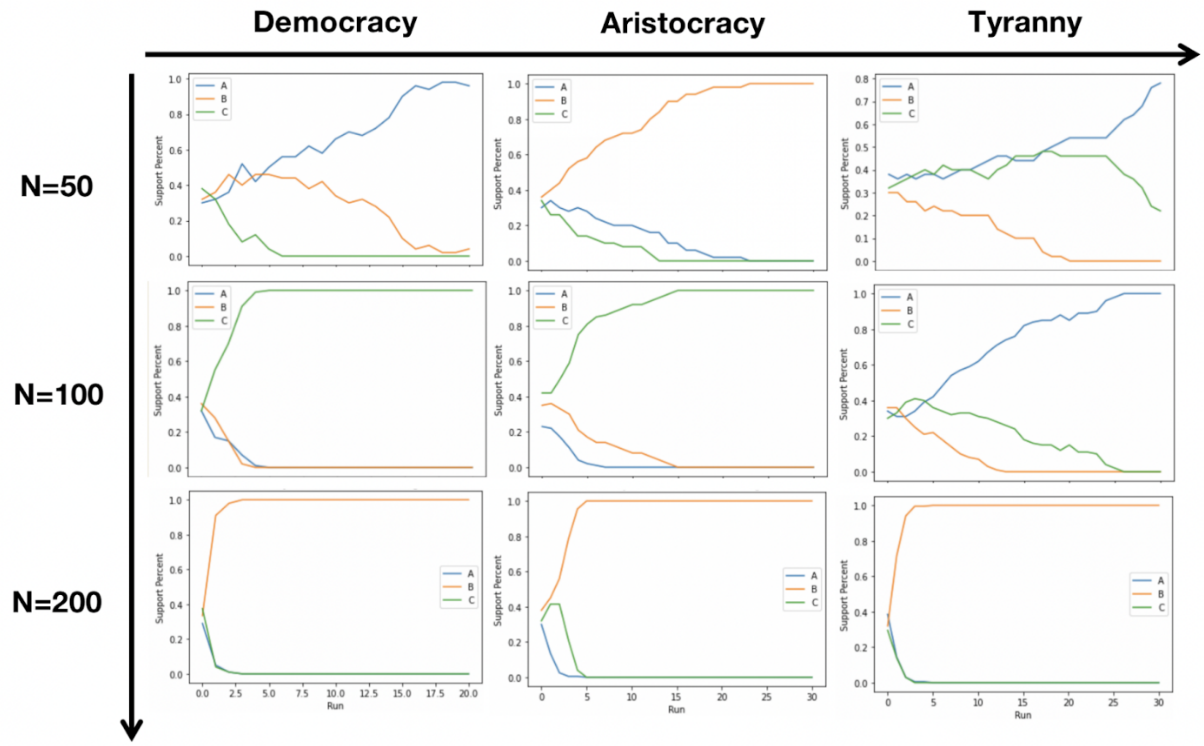


Fig. 5: Supporting rate changes

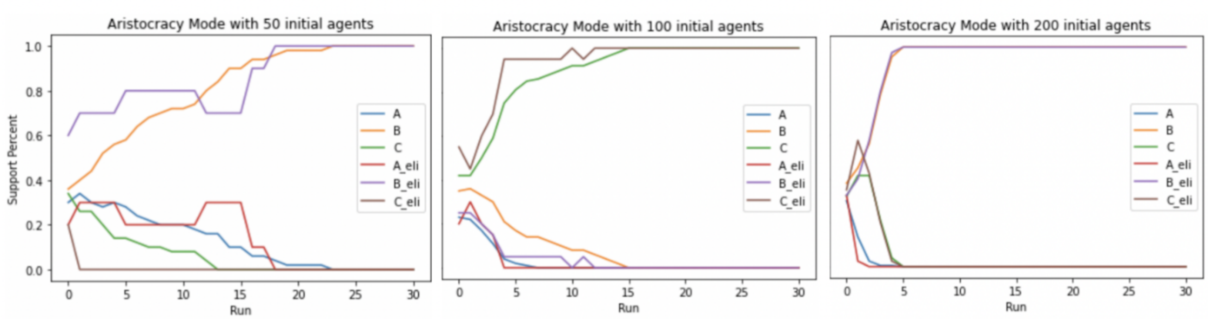


Fig. 6: Rate changes in Aristocracy.

Another limitation is that our study did not quantify the information spreading efficiency and dispersion degree of three options because of the time limitation. This deficiency leads to the lack of persuasion in our conclusion. Potential solution might be to conduct statistical tests such as correlation analysis and sensitivity analysis to present relations among variables used in the model.

Overall, our simulation study highlights the importance of organizational structures in information spreading and decision-making processes. We hope that our work will contribute to the ongoing discussion on how to design effective organizational structures that promote information diffusion and decision-making efficiency in groups.

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