REPORT

BUSINESS INTELLIGENCE WORKPLACE

PROJECT P02: AGENT BASED SIMULATION FOR DECISION MAKING

Author: Joanna Stawik

Group: Fridays 11:15

Table of Contents

1 INTRODUCTION

1.1 BACKGROUND OF THE PROJECT

The project focuses on decision-making within a company that values the opinions of its employees. Before making any major decision, the company holds meetings and seeks a positive consensus among the employees. If all employees agree, the decision is accepted. However, when opinions are mixed, the company allows more time for employees to reconsider and arranges another meeting after a month.

1.2 AIM OF THE PROJECT

The aim of this project is to conduct an agent-based simulation in order to determine the minimum convincing ability of "yes" agents needed to achieve a positive consensus among employees in the company. Also, the project aims to analyze the dynamics of the decision-making process, explore the effect of the convincing ability on positive consensus, and provide insights for optimizing the decision-making process (as a function of p). Moreover, the project aims to study the impact of vector length ($L = 50, 100, 500$) on positive consensus state.

2 METHODOLOGY

The methodology used in this project involves implementing an agent-based simulation using the Spyder environment and Python programming language. The simulation is designed to model the decision-making process in a company where employees express two opinions ("yes" or "no") on a proposed decision. The goal is to investigate the minimum convincing ability required for "yes" agents to achieve a positive consensus among all employees.

The code begins by importing the necessary libraries, including NumPy for random number generation and Matplotlib for data visualization. The simulation is then defined within the simulate function, which takes parameters such as the vector length (L), initial agreement fraction (x), number of configurations (N), and the convincing ability of "yes" agents (p).

In the simulate function, first a time step loop is initiated, where each iteration represents a single time step in the simulation. At each time step, the state of the system is updated by considering interactions between neighboring agents. The decision-making rules between agents are implemented here based on the given probabilities and conditions outlined in project's requirements.

The simulation runs for a maximum number of time steps (t_{max}), and if a positive consensus is reached (sum of the grid equals L or $-L$), the exit count is incremented by one. After the simulation runs for all configurations, the exit probability is calculated as proportion of the exit count to the total number of configurations (*exit_count / N*).

The main code block sets the parameters for the simulation, including the vector length (L), initial agreement fraction (x), number of configurations (N), and the step size (*step*) for the convincing ability (p). A list of p values is generated incrementally, and for each p value, the simulation is executed by calling the simulate function. The results are stored in the *simulation_results* and *exit_probabilities* lists for further analysis.

Finally, the exit probabilities are plotted against the corresponding convincing ability values using Matplotlib. The resulting plot visualizes the relationship between the convincing ability of "yes" agents and the probability of achieving a positive consensus. The plot is labeled and titled appropriately for clarity and interpretation.

3 RESULTS AND DISCUSSIONS

3.1 ESTIMATING THE CONVINCING ABILITY OF "YES" AGENTS

First of all, it is crucial to define exit probability *E*. Exit probability *E* is a fraction of configurations for which a positive consensus is reached.

Figure 1 represents the plot of exit probability *E* as function of *p* for vector of length $L = 50$.

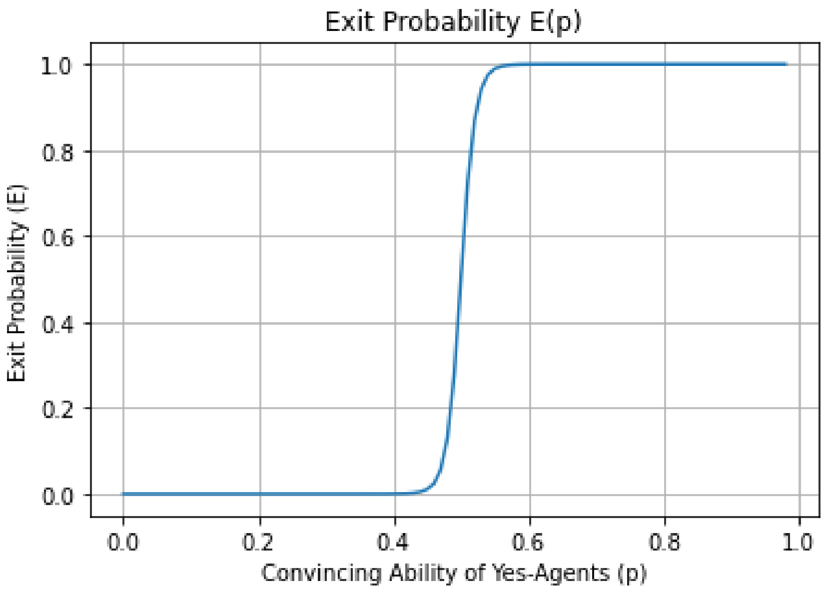

Figure 1. Exit probability E as function of p for vector of length L = 50.

The minimum value of the convincing ability of yes-agents *p* for which all the employees would agree to take the decision is **67%**, as evidenced by a snippet from the Spyder environment (Figure 2).

tuple	2	(0.65, 0.99998)
tuple	2	(0.66, 0.99999)
tuple	2	(0.67, 1.0)
tuple	2	(0.68, 1.0)

Figure 2. Snippet from the Spyder environment: first column is describing a type of variable, second column is representing the size of the variable, third column is searched value, in which the first number is probability p, and the second is exit probability.

3.2 PROBABILITY OF CONSENSUS AT 50%: FINDING THE TIPPING POINT

To determine the value of p at which we would expect to reach a positive consensus state with a 50% probability, we can analyze the simulation results and observe the exit probabilities corresponding to different convincing abilities.

Based on the plot generated (Figure 1), we can observe the convincing ability values (*p*) on the x-axis and the corresponding exit probabilities on the y-axis. We look for the point on the plot where the exit probability is approximately 0.5.

The reason for this expectation is that when the exit probability is around 0.5, it indicates an equal chance of achieving a positive consensus or failing to reach consensus. This suggests a balance between the convincing abilities of the "yes" and "no" agents. When the exit probability is close to 0.5, it implies that both sides have a relatively equal chance of influencing the opinions of their neighbors. Therefore, the value of *p* at which the exit probability is around 0.5 represents a situation where consensus is equally likely to occur or not to occur.

By identifying the convincing ability value (*p*) at which the exit probability is approximately 0.5, we can determine the threshold at which the "yes" agents have a reasonable chance of flipping the opinions of the "no" agents and reaching a positive consensus state with a 50% probability.

The probability of consensus at *p* = 50% is **50,038%** as evidenced by a snippet from the Spyder environment (Figure 3).

tuple	2	(0.49, 0.27654)
tuple	2	(0.5, 0.50038)
tuple	2	(0.51, 0.72373)

Figure 3. Snippet from the Spyder environment: first column is describing a type of variable, second column is representing the size of the variable, third column is searched value, in which the first number is probability p, and the second is exit probability.

3.3 The Impact of Convincing Ability on Consensus Formation

At the lower end of the *p* values (up to p = 0.47), we see that the exit probability remains close to 0. This suggests that the convincing ability of the "yes" agents is insufficient to flip the opinions of the "no" agents consistently. As a result, reaching a positive consensus state becomes highly unlikely.

As we move towards *p* values around 0.47, the exit probability starts to increase rapidly. This indicates that there is a critical threshold in the convincing ability of the "yes" agents. Beyond this threshold, the "yes" agents become more influential, and the probability of achieving a positive consensus state rises significantly.

At around *p* = 0.55, the exit probability reaches its highest points, close to 1. This indicates that the convincing ability of the "yes" agents is strong enough to almost guarantee a positive consensus. The "yes" agents have a high probability of successfully flipping the opinions of the "no" agents, leading to a strong agreement among the employees.

Between *p* values of 0.48 and 0.54, we observe an almost vertical line in the plot. This suggests a sharp transition region where a slight increase or decrease in the convincing ability of the "yes" agents has a significant impact on the probability of achieving consensus. This range represents a delicate balance where the opinions of the "no" agents can be easily influenced, resulting in a rapid shift from a lack of consensus to a positive consensus state.

Overall, the curve demonstrates that the probability of reaching a positive consensus state is highly sensitive to the convincing ability of the "yes" agents, with a sharp transition region where small changes in p can have a substantial effect on the consensus outcome.

3.4 EXPLORING CONSENSUS DYNAMICS IN VARYING VECTOR LENGTHS

- **For L = 100:**

Figure 4 represents the plot of exit probability *E* as function of *p* for vector of length *L* = 100.

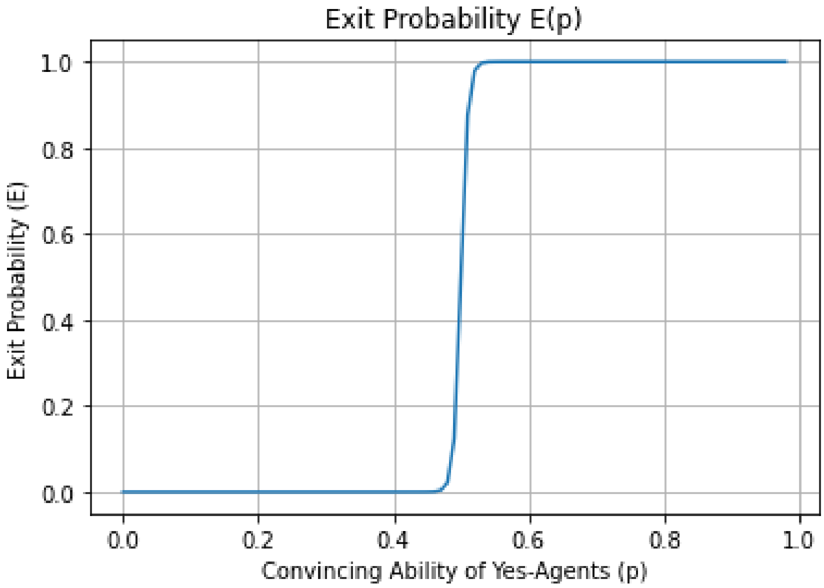

Figure 4. Exit probability E as function of p for vector of length L = 100.

The minimum value of the convincing ability of yes-agents *p* for which all the employees would agree to take the decision is **58%**, as evidenced by a snippet from the Spyder environment (Figure 5). This is much smaller value than it was when *L* = 50. It means that the larger system allows much faster to reach the positive consensus state.

tuple	2	(0.56, 0.99995)
tuple	2	(0.57, 0.99999)
tuple	2	(0.58, 1.0)
tuple	2	(0.59, 1.0)

Figure 5. Snippet from the Spyder environment: first column is describing a type of variable, second column is representing the size of the variable, third column is searched value, in which the first number is probability p, and the second is exit probability.

For *L* = 100, the value of p at which we would expect to reach a positive consensus state with a 50% probability remains similar to the case of *L* = 50. The threshold value of *p* is around 0.5, indicating a balanced influence between the "yes" and "no" agents. The probability of consensus at *p* = 50% is slightly higher than the corresponding value for *L* = 50. The larger system size allows for a slightly higher chance of achieving consensus at the same convincing ability level.

The probability of consensus at p = 50% is **50,14%** as evidenced by a snippet from the Spyder environment (Figure 6).

tuple	2	(0.49, 0.12357)
tuple	2	(0.5, 0.5014)
tuple	2	(0.51, 0.87561)

Figure 6. Snippet from the Spyder environment: first column is describing a type of variable, second column is representing the size of the variable, third column is searched value, in which the first number is probability p, and the second is exit probability.

When the length of the vector is increased to L = 100, the transition region where the exit probability exhibits a vertical line becomes more prominent. The plot of exit probability as a function of p still shows a similar trend as observed for L = 50. However, the range of p values where the vertical line appears, indicating a rapid transition in the exit probability, becomes narrower.

In this reduced range (around p = 0.48 to 0.52), even a slight variation in the convincing ability of the "yes" agents leads to a significant change in the probability of reaching a positive consensus state. The opinions of the "no" agents become highly susceptible to influence, resulting in a sharp transition from a lack of consensus to a positive consensus state or vice versa.

The increased length of the vector amplifies the sensitivity of the system to changes in p within this range. It highlights the critical role of the convincing ability parameter in determining the dynamics of opinion formation and the probability of achieving consensus among the employees.

Therefore, when the vector length is increased to L = 100, the vertical line in the plot becomes more pronounced, emphasizing the importance of the convincing ability of the "yes" agents in driving consensus outcomes.

4 Conclusion

In conclusion, *The agent-based simulation for decision making* project aimed to analyze decision-making dynamics within a company by determining the minimum convincing ability required for "yes" agents to achieve a positive consensus among employees. The study also explored the effect of convincing ability on consensus state and investigated the impact of vector length L on the probability of reaching a positive consensus state.

The results of the simulation revealed that the convincing ability of "yes" agents plays a crucial role in achieving consensus. At lower convincing ability values, a positive consensus state becomes highly unlikely. However, as the convincing ability increases, the probability of reaching a positive consensus rises significantly. A critical threshold was observed, beyond which the "yes" agents became more influential, leading to a higher chance of consensus. The plot demonstrated a sharp transition region, where slight variations in convincing ability had a significant impact on consensus outcomes.

The analysis of different vector lengths showed that the larger the system size, the more prominent the transition region became. For example, when the vector length increased from L = 50 to L = 100, the range of convincing ability values corresponding to the vertical line in the plot narrowed. This indicated that a smaller range of convincing abilities was required to drive consensus outcomes in larger systems. The sensitivity of the system to changes in convincing ability within this range became more pronounced, emphasizing the importance of the convincing ability parameter in determining consensus dynamics.

The results presented in Table 1 provide valuable insights into the relationship between the vector length (*L*), the minimum convincing ability of "yes" agents required for unanimous agreement, and the probability of achieving consensus at $p = 50\%$.

Table 1. Results of simulation for different values of L.

L	**Minimum convincing ability of yes-agents *p* for which all the employees would agree to take the decision**	**The probability of consensus at *p* = 50%**
50	67 %	50.038 %
100	58 %	50.14 %

When considering a vector length of $L = 50$, the minimum convincing ability of "yes" agents necessary for all employees to agree on a decision was found to be 67%. This means that when the convincing ability of "yes" agents falls below this threshold, it becomes increasingly difficult to reach a positive consensus state. The probability of achieving consensus at $p = 50\%$ was determined to be 50.038%.

In comparison, when the vector length was increased to $L = 100$, the minimum convincing ability of "yes" agents required for unanimous agreement decreased to 58%. This suggests that in larger systems, consensus can be reached with a lower convincing ability. The probability of consensus at $p = 50\%$ also slightly increased to 50.14%.

These findings highlight the influence of vector length on the decision-making process within the company. A larger system size allows for a slightly higher chance of achieving consensus at the same convincing ability level. Additionally, the decrease in the minimum convincing ability required for consensus suggests that larger systems may facilitate faster decision-making processes, as employees are more easily persuaded to reach an agreement.

Overall, the project provided insights into the decision-making process within a company and the factors influencing consensus formation. Understanding the minimum convincing ability required for achieving positive consensus can help optimize the decision-making process and improve organizational outcomes. The findings highlighted the critical role of the convincing ability of "yes" agents and the impact of vector length on consensus outcomes, emphasizing the need for effective communication and persuasion strategies in driving consensus among employees.