Votes of Influence:
Simulating Social Dynamics in Turkish Politics

Project Report

- Project title : Votes of Influence: Simulating Social Dynamics in Turkish Politics
- Course name and code : Agent Based Modeling in Information Systems – MIS485
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Overview

Introduction

Background of the Problem

Traditional segregation modals focus on spatial clustering driven by agents' preferences for local similarity. While these modals illustrate how people's preferences can change their location entirely it doesn't specify how an agents' preferences were created and overlook the idea underlying attitudes of those preferences or how attitudes might change through social interaction.
In contemporary political and social contexts, individuals not only self-select neighborhoods based on similarity or differentiation but also influence each other's opinions, creating feedback loops that can fuel polarization.
The researches show that people generally select 70% similarity near them. However, we were unsure how these preferences would affect the community's polarization and happiness based on their environmental preferences.

Primary Objectives:

Simulation of Social Dynamics in Voting Behavior: How social interactions, demographic distributions, and personality traits influence voting patterns in Turkey's political landscape.
Analyzing Polarization and Persuasion: Investigate the role of political polarization and social persuasion in shaping individual and collective voting tendencies.
Evaluation of Regional Differences: Explore how regional variations (e.g., Ege vs. Karadeniz) affect political leanings, happiness levels, and social similarity among individuals.
Quantify Metrics of Social and Political Structure: Showcasing polarization based on agents' behaviors and seeing percentage of unhappy or isolated agents to understand the impact of various factors on social harmony.
Explore the Impact of Political Campaigns: Simulate the influence of political campaigns (on/off toggle) on agent behavior, voting outcomes, and polarization dynamics.

Relevance to agent-based modelling:

This project uses Agent-Based Modeling (ABM) to simulate voting behavior in Turkey because it captures individual behaviors, social interactions, and emergent phenomena, which are essential for understanding dynamics like polarization and regional differences. Each agent represents a voter with unique attributes, interacting within social and geographical contexts.
Unlike traditional models, which aggregate data and oversimplify outcomes, ABM allows us to observe how micro-level behaviors drive macro-level changes. It's ideal for exploring complex systems where local interactions lead to large-scale effects, such as political shifts or clustering.
ABM was chosen because it supports spatial variability, social networks, and experimentation with scenarios like political campaigns. This flexibility makes it the only suitable approach for achieving our goals and gaining meaningful insights into voter dynamics.

Overview of the Model

Summary simulates the dynamics of political polarization in Turkey by integrating agent-based interactions, spatial segregation, and external campaign influences. Each agent represents a segment of the population with distinct attributes such as political stance, persuasiveness, and susceptibility to persuasion. The simulation is set within a scaled-down representation of Turkey, featuring seven regions with unique demographic and political characteristics.

Agents interact within their local environment, adapting their political preferences based on neighbor similarity, persuasion dynamics, and external events like political campaigns. Over time, agents relocate to achieve satisfaction, forming clusters of like-minded individuals. The model tracks key metrics, including polarization, happiness, and shifts in political stances, providing a comprehensive view of how micro-level behaviors drive macro-level societal changes.

This framework captures the interplay of social and political forces, offering a detailed lens into the formation of ideological divides and the impact of targeted interventions. Its adaptability and realism make it a valuable tool for exploring the complex nature of political and social dynamics.

ODD Protocol

Purpose

The purpose of this model is to simulate the dynamics of political polarization within a heterogeneous population distributed across distinct geographic regions. The model explores how individuals with varying political leanings, susceptibility to persuasion, and social preferences interact, leading to changes in their political stances, neighborhood satisfaction, and overall societal polarization.
By integrating spatial dynamics, individual-level attributes, and external campaign effects, the model aims to study the interplay between diversity, extremity, isolation, and persuasion in shaping political landscapes over time.

Goals of the Model

Predict Real-World Polarization Trends: To produce simulations that align closely with observed polarization trends, offering insights into future ideological shifts.
Validate Social Influence Theories: Examine existing theories of people's behavior on similarities near them and check if it causes polarization using model outcomes.
Facilitate Comparative Analysis: Offer a computational framework for comparing regional and national polarization patterns.

Intended Application

Our model serves as an example of how a society drives its movement and social interactions based on their preferences on their environment and their initial values such as persuasiveness. Hence, it can be a good candidate for social experiments on political issues and behavioral experiments.
Creating a small Turkey with the mindset of making as reel as possible made the model suitable for simulating the future while the behaviors of the people and their political choice are changing. In each choice, as finding a neighborhood that reflects us more or with a more diverse setting, we are creating a future where people will be clustered hence not changing so much or a future where they will be living with different minded people in harmony and accepting the change.

Entities, State Variables, and Scales

Entities

Each human agent in the model represents a segment of Turkey's population, scaled to represent 33,000 individuals per agent. In total 1818 human agents were implemented. The agents are categorized into five distinct subgroups based on their political spectrum, with each subgroup corresponding to a specific color:
Purple (the far left), Red (center left), White (undecided individuals), Light Yellow (center-right), Yellow (the far right)

This color-coded categorization visually illustrates the distribution of political leanings within the population, from left to right along the political spectrum.
Entity environment represents Turkey's landscape with 7 different regions each with their own colors. With different colors representing regions the human turtles can be moved on it; while the black patches represent the outside of the country. With 3705 patches Turkey' scaled map frame is 1/210.

State Variables

Turtle-Specific Parameters

Parameter Name	**Parameter Type and Units**	**Meanings**
region	Static, one element of list of regions as in Turkey (Marmara, Ege…)	The region the agent is born at.
initial-stance	Static, three types (right-voted, left-voted, undecided)	The initial political stance of the agent
persuasiveness	Static, integer [0,10]	Ability to persuade others ranging from least persuasive with 0 value to the most with 10 value
susceptibility	Static, integer [0,10]	Likelihood of being persuaded ranging from least susceptible with 0 value to the most with 10 value
my-%-similar-wanted	Static, random integer [0, %-similar-wanted]	The turtle's own percentage of that turtle's neighbors are the same color as the turtle

Turtle-Specific State Variables

Variable Name	**Variable Type and Units**	**Meanings**
political-stance	Dynamic, three types (right-voted, left-voted, undecided)	Represents which party the agent to vote
has-changed	Dynamic, Boolean	Shows if political stance has changed over time
political-spectrum	Dynamic, integer [-50,50]	Represents political leaning from left (-50) to right (+50)
happy	Dynamic, Boolean	Indicates whether a turtle is satisfied based on its neighborhood: at least a certain percentage of its neighbors must be the same color as the turtle (%-similar-wanted), and at least another percentage must be of a different color (%-different-wanted).
similar-nearby	Dynamic, integer	Represents how many neighboring turtles of a turtle with its color
other-nearby	Dynamic, integer	Represents how many neighboring turtles of a turtle with another color

Environment-Specific State Variables: There are special patches which have color of black representing they are outside of Turkey. Turtles in the model do not move to these patches thus remaining on the map.

Global Variables

Variable Name	Variable Type and Units	Meanings
percent-similar	Dynamic, real [0,100]	The percentage of the turtles' having neighbors are the same color as that itself
percent-unhappy	Dynamic, real [0,100]	The percentage of turtles unhappy
percent-isolated	Dynamic, real [0,100]	The percentage of turtles having most of its neighbors share the same color as itself
percent-extreme	Dynamic, real [0,100]	The percentage of turtles in extreme polars
percent-diverse	Dynamic, real [0,100]	The percentage of turtles having most of its neighbors have different color from itself
shift-score	Dynamic, real [0,100]	The percentage of agents shifting from one political-stance to another
percent-right	Dynamic, real [0,100]	Percentage of turtles voting to right
percent-left	Dynamic, real [0,100]	Percentage of turtles voting to left
percent-null	Dynamic, real [0,100]	Percentage of turtles that are undecided voters
turtle-extreme	Static, turtle	One of turtles in extreme polars
turtle-moderate	Static, turtle	One of turtles from moderate political spectrum

Scales

Spatial Scale: The environment is structured as a 2D grid map of Turkey having 3705 patches with a scaled frame of 1/140.000. The range of happiness between turtles is within a radius of 3 turtles on neighbors since individuals may be influenced by their living territory. Happiness may be influenced by neighbors, being in radius 1, people in neighborhood, being in radius 2, and people in living territory, being in radius 3. But interaction between turtles is within a radius of 1 turtle on neighbors since individuals' most interactions are with their neighbors.

Temporal Scale: In model, each tick represents two weeks in reality. There is one specific event tied to time intervals, political campaigns. Political campaigns happen every 4 years in Turkey, in model it happens every 100 ticks representing 200 weeks – approximately 4 years.

Behavioral or Interaction Scales: Turtles' movement is based on their happiness as a Boolean, if at least a certain percentage of the turtle's neighbors being the same color as the turtle (%-similar-wanted), and at least another percentage being of a different color (%-different-wanted). The interaction between turtles begins with happiness Boolean variable being true. In the interaction process, the most persuasive turtle of the two increases the other one's political spectrum as the size of its susceptibility (if its political-spectrum is more, otherwise it decreases), remaining in the range from -50 to +50.

Turtles' political-spectrum determines their color and political-stance and as their political-spectrum changes their color and political-stance may change unless they remain in the range. The range for political-spectrum is from -50 to +50; for political-stance it is "left" as if its political-spectrum – aka PS for the rest – is in [-50,-5), it is "undecided" as if its PS is in [-5,5), and it is "right" for the remaining range. Turtles' color, on the other hand, is magenta if its PS in [-50,30), red if its PS in [-30,-5), white if its PS in [-5,5), light yellow if its PS in [5,30), and lastly yellow if its PS in [30,30]

Extreme turtles, whose political spectrum is either more than or equal to 40 or less than or equal to -40, can have a susceptibility of a value from 0 to 3 while the others may have from 0 to 10.

Political campaigns have an effect on all turtles, except whose political-spectrum is either more than 45 or less than -45, increasing or decreasing political-spectrum based on the political-campaigns' direction.

Process Overview and Scheduling

Processes: The model operates on a weekly basis, with each tick representing one week. During each tick, agents evaluate their surroundings and may change their coordinates if they are dissatisfied with their environment. This behavior is guided by their preferences, which depend on whether they desire to live among similar individuals or in a more diverse setting.
When agents interact, their political views play a central role in the interaction. The outcome of these interactions depends on their levels of persuasiveness and susceptibility. The "weaker" side in an interaction will shift its political spectrum to align more closely with the "stronger" side's preferences.
As the model progresses, agents who find a location that satisfies their preferences—based on their individual thresholds for diversity and similarity—will stop moving. Over time, this dynamic creates clusters of like-minded individuals, illustrating patterns of polarization among agents with different behavioral tendencies.
Schedule: The model begins with the 2023 general election in Turkey, which serves as the starting point. This initialization reflects the distribution of right-leaning and left-leaning individuals based on election data. The population is modeled to closely align with real-world Turkish demographics, particularly in the initial week, where more individuals sprout from the Marmara Region, reflecting its higher population density compared to other regions.
Each simulation step (tick) represents one week, during which individuals interact and move. Initially, people begin moving with the goal of finding a location that aligns with their behavioral preferences and makes them happy. Once an individual finds such a location, they settle there and stop moving.
For those unable to find a suitable location, the process continues in subsequent ticks. In addition to searching for a better place, these individuals interact with others, either attempting to persuade or being influenced by those they encounter.

Design Concepts

Basic principles:
The model is based on theories from political science and behavioral economics, focusing on how people's political views influence their behavior and interactions. It uses principles of self-interest, where individuals seek environments that align with their values and goals.
The idea of social influence, where individuals persuade or are persuaded by others, drives interactions. This approach helps simulate political polarization, showing how people group together based on similar beliefs, influenced by their interactions with others. The model uses these concepts to understand how political divisions form and change over time.

Emergence:

In this model, the main emergent result is the polarization of agents based on their political views. Agents move to locations where they feel comfortable, creating clusters of like-minded individuals. This behavior is influenced by agents' political preferences, the region they belong to, and their interactions with others. These interactions lead to agents influencing one another's political views, further contributing to the system's polarization.
The system's behavior is emergent, as it depends on agents' adaptive decisions, which result in complex, unpredictable patterns. The model's rules do not directly impose polarization, but rather it emerges through agent behaviors and interactions.
Adaptation:
Agents adapt by moving if they are unhappy and by shifting their political spectrum if they are persuaded.

Objectives:

The objective measure in the model represents agents' happiness in finding a location where their political preferences are satisfied. It models the degree of comfort an agent feels in its surroundings based on the political similarity or diversity of its neighbors.

Variables affecting this measure include agents' political preferences and in which percentage they want similar and different people near them. The measure is calculated by comparing the agent's political alignment with its neighbors, assessing whether it meets a predefined satisfaction threshold. This measure reflects agents' desire to live in politically similar or diverse environments, driving their movement and interactions.

Learning:

Agents do not explicitly learn over time; they immediately react to local conditions (happiness, persuasion).

Prediction:

No forward-looking or strategic planning; agents respond reactively.

Sensing:

Agents sense the political preferences of their neighbors and their own satisfaction with the surrounding environment. They also sense the density of similar and diverse political views within their local area. The range of sensing is limited to nearby agents within a 3 radius.

Agents know the political preferences of their neighbors accurately while interacting with each other. This assumption simplifies the modeling of the sensing process while allowing for realistic decision-making about relocation. The rationale is to reflect agents' ability to evaluate their immediate social and political environment.

Interaction:

In the model, direct interaction occurs between neighboring agents within a radius, where political stances are influenced based on persuasiveness and susceptibility. Agents with differing political views can persuade each other.

Mediated interaction happens when external events, like political campaigns, influence agents' political stances globally. Campaigns affect agents by shifting their views based on their political spectrum, but specifically not targeting extreme agents.

Direct interaction is based on spatial proximity and individual behaviors, while mediated interaction is driven by campaigns that affect model globally.

Stochasticity:

Stochasticity is used to capture natural variability and unpredictability in agent behaviors and interactions and in our model it is captured by:

Initial political spectrum: Each agent is assigned a political spectrum value randomly within certain ranges. This introduces variability in political views without explicitly modeling the causes of these differences.

Agent susceptibility and persuasiveness: These are randomly set within a range to vary the likelihood of agents changing their political stance or persuading others. This randomness simulates the variation in personal traits and decision-making.

Agent movement: Turtles move randomly when unhappy, introducing unpredictability in their location and interactions.

Collectives:

No explicit formal collectives, but region acts as a categorization.

Observation:
In this model, key outputs observed from the simulations include:
Percent of unhappy agents: This is calculated as the percentage of agents whose political stance is different from their desired similarity threshold.
Political spectrum distribution: The distribution of political stances (left, right, undecided) across agents is tracked to observe shifts in the population over time.
Polarization score: This score combines isolation, extremity, and diversity to represent the overall political polarization in the model.
Shift score: Tracks the percentage of agents who change their political stance.
Change in one extreme agent: Tracks one specific agent which has an initial extreme political score throughout their change of political ideas.
Change in one moderate agent: Tracks one specific agent whose initial political score is moderate throughout their change of political ideas.
The observations are collected using summary statistics such as means and proportions across the agent population, observed once per simulated tick.

Initialization:
Set Up Environment: In the model, patches' color is determined by the inserted picture of a map of Turkey. Scaling of that map is explained in Scaling part.

Set up Turtles: Turtles are born at specific locations each of one representing the 7 regions of Turkey, which is set as a list at the very first step. These locations are selected as one of the patches from all of them based on their related regions, becoming the region of the turtle itself. Initialization of those turtles in terms of their regions, and also randomized regions, associated with political-spectrum is going to be well defined at the next section, Input Data, which is related to the results of the 2023 Election in Turkey. The shape and size of turtles is set in this part as "person" and 1.3 for a fancier appearance. The property "has-changed" is set as 'false' as default, and "persuasiveness" is set as a random number. Susceptibility of turtles is set as randomized numbers less than 4 for extreme turtles, and randomized numbers less than 11 for the others, making the model more realistic since people with extreme political-spectrum would be much less likely to be persuaded in real. As initializing political-spectrum, color and political-stance, and also initial-stance are set based on the turtle's political-spectrum. In the interface we would like to see the difference of political-spectrum changes in between one extreme turtle and one moderate turtle, so 'turtle-extreme' and 'turtle-moderate' are set at the initialization too.

Set Up External Events: The effects of political campaigns towards right and left are set as they increase or decrease 5 degrees of the political-spectrum of turtles, except extremes.

Input Data:

The real-life voting data provided in the table was used as the foundation for determining the number of agents in the model and how they are distributed across the seven regions. To achieve a manageable model with fast processing times while maintaining real-world relevance, we applied a ratio of 1:33,000, representing a downscaled environment. This ratio allowed us to create a smaller, yet statistically representative, version of the population.

Each vote in the dataset was translated into a corresponding turtle (agent), with the political spectrum of each turtle derived from the region's real-life voting percentages. For example, regions like Ege and Karadeniz, which exhibit distinct political leanings compared to the national average, were assigned a proportionate number of agents with political spectra that reflect these regional variations. This distribution helps ensure that the model more accurately mirrors the political diversity and regional characteristics of Turkey.

By aligning the agent distribution with both population size and political leaning, the model is able to simulate regional interactions and political shifts more effectively. This approach not only reflects the real political landscape but also facilitates a deeper understanding of how individuals with different political stances interact within each region. The result is a simulation that is both realistic in its regional representation and optimized for computational efficiency.

	Kayıtlı Seçmen Sayısı	**Turtle Sayısı**	**Sprout Turtle**	**SAĞ OY ORANI**	**SOL OY ORANI**	**SAĞ OY SAYISI**	**SOL OY SAYISI**	**Kararsız oy sayısı**
Marmara	18.822.183	570	439	49,59	50,41	218	221	0
İç	9.701.530	294	162	59,04	40,96	96	67	0
Akdeniz	7.663.506	232	101	49,22	50,78	50	51	0
Ege	8.154.834	247	116	42,25	57,75	49	67	0
Güney Doğu	5.275.421	160	28	49,48	50,52	14	14	0
Karadeniz	6.036.723	183	51	65,36	34,64	34	18	0
Doğu	4.343.306	132	-	54,09	45,91	-	-	0
Randomized Oy Sayısı			921	52,18	47,82	392	350	182
	SUM:	1.818	1.818			900	918	182

Submodels:

Happiness Submodel: Determines an agent's happiness based on the political similarity of its neighbors. Happiness is determined if a sufficient percentage of neighbors share the same political spectrum or with different-wanted it can be based on the different people we have in a 3 radius. my-%-similar-wanted (individual tolerance), similar-nearby, total-nearby similar-wanted and different-wanted works in this submodel. It creates a simulation of social cohesion based on political similarity.

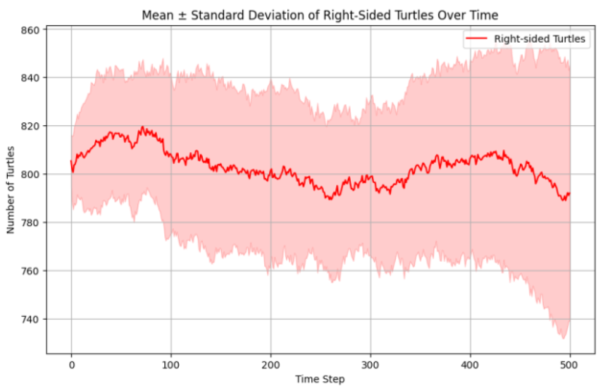
Movement Submodel: Makes the movement of agents based on their happiness to find neighbors with similar political views. Unhappy agents randomly move until they find a suitable neighborhood. Reflects individuals seeking like-minded communities or diverse communities based on our input in the model.

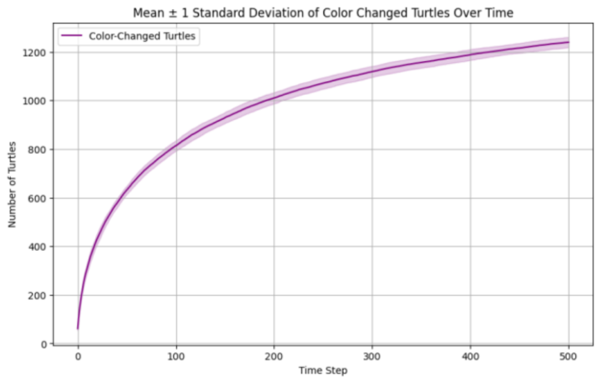
Persuasion and Political Spectrum Change Submodel: Simulates political persuasion between agents. Agents' political views shift based on interactions with diverse neighbors. persuasiveness, susceptibility, political spectrum is used in this model. Model shows social influence and political shifts in real-world settings.

External Events (Political Campaigns) Submodel: Models the effect of political campaigns on modarate agents. Political campaigns shift the stance of agents (left or right). Political campaigns by right-wing (R) or left-wing (L) is used in this model. Each of them makes some agents political-spectrum change in a way they tend to like left-wing campaigns make people’s political range to shift on more left side. Simulates real life political campaigns and the impact of them.

Experimentation

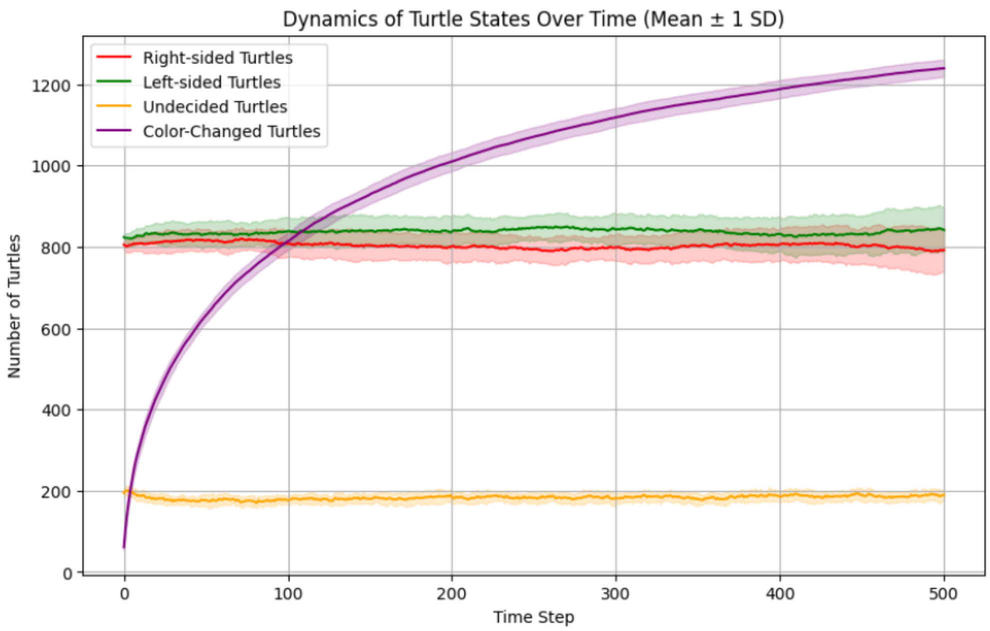
Replication





Observations from the Change in the Number of Right Sided Turtles
Fluctuations: While the number of right-sided turtles starts stable, there are observable fluctuations as time progresses.
Key Observation: Variability increases slightly over time, though the mean remains steady, reflecting minor reclassification dynamics.
Later Stability:
Towards the end, the number stabilizes within a tighter range, indicating equilibrium has been reached.

Observations from the Change in the Number of Color Changed Turtles
Single-State Focus: The graph isolates the color-changed turtles, showcasing their growth trajectory.
Key Observation: Steady increase in the early and middle stages (ticks 0-300), followed by a plateau in the later stages as the system stabilizes.
Variability: The shaded region highlights variability across runs, which is narrow, suggesting consistent behavior in the system's dynamics.



Lines and Shaded Regions:

Purple (Color-Changed Turtles):

Represents the average number of turtles that change color over time.

The shaded region indicates the variability in outcomes across different runs.

Key Observation: Rapid increase in color-changed turtles at the early stages (ticks 0-100), leveling off towards the later stages (ticks 400-500) as most turtles have transitioned.

Red (Right-Sided Turtles):

Represents the average number of turtles categorized as "right-sided."

The red line stabilizes early, with minor fluctuations throughout the time steps.

Key Observation: The number of right-sided turtles remains relatively stable, with minimal changes over time.

Green (Undecided Turtles):

Tracks turtles that have not yet transitioned into a specific state.

Key Observation: Slight variations but overall stability suggest limited movement between states.

Yellow (Left-Sided Turtles):

Represents turtles classified as "left-sided."

Key Observation: Maintains a consistent lower number compared to other states, showing limited interaction or transitions.

Interactions Between States:

Initial Stage (Ticks 0-100):

Rapid growth in color-changed turtles dominates the dynamics.

Stable numbers for other turtle states indicate the system prioritizes transitions over reclassification.

Middle Stage (Ticks 100-300):

Growth in color-changed turtles slows as the system reaches saturation.

Other states remain mostly unchanged, emphasizing the dominance of the "color-change" dynamics.

Later Stage (Ticks 300-500):

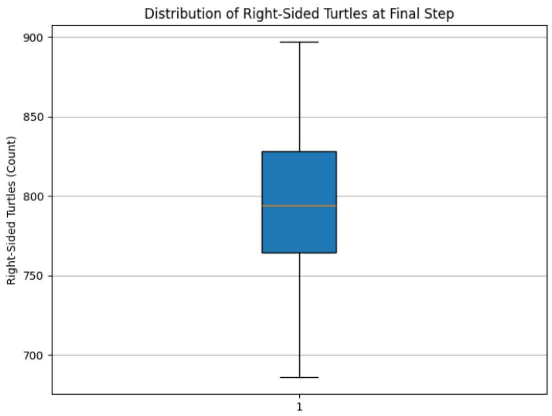
Color-changed turtles dominate the population, stabilizing near maximum values.

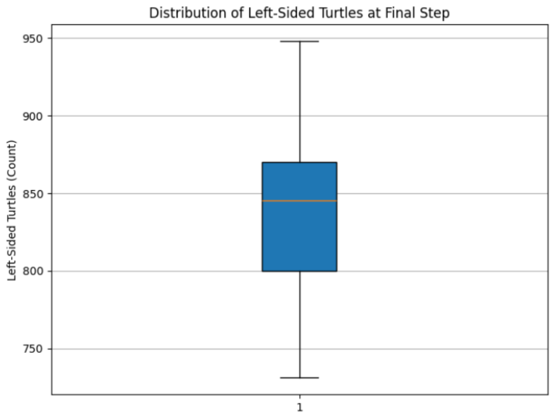
Other states (e.g., right-sided and left-sided turtles) retain their proportions with minimal shifts.

Insights and Applications

Model Robustness: Shaded regions show minimal variability in most graphs, indicating consistent behavior in simulations.

Varying Random Seeds: It was essential for ensuring the robustness, reliability, and generalizability of our model. It captured the stochastic variability of our simulations, allowing us to assess whether our results are consistent or highly sensitive to randomness.
By testing with different seeds, we evaluated how well our model generalizes, uncover edge cases, and understand its sensitivity to initial conditions. Aggregating results across seeds provides a holistic view of our model's performance, smoothing out randomness to produce more reliable conclusions.
Ultimately, using multiple random seeds helped us identify potential vulnerabilities, refine our model, and ensure its stability across diverse scenarios.





Boxplot 1: Distribution of Right-Sided Turtles at Final Step

Key Elements:
Box (Blue Rectangle): Represents the interquartile range (IQR), which contains the middle 50% of the data for right-sided turtles. The bottom edge corresponds to the 25th percentile (~750 turtles), and the top edge corresponds to the 75th percentile (~825 turtles).
Median (Line Inside the Box): The median count of right-sided turtles is approximately 800, indicating that half of the runs ended with this value or higher.
Whiskers: Extend to approximately 700 (minimum typical value) and 900 (maximum typical value), representing the range of typical values excluding outliers.
Outliers: No outliers are present, indicating consistent behavior across the runs.

Observations:
Median: Right-sided turtles consistently cluster around the median, showing limited variability.
IQR: The range of 750-825 turtles suggests a relatively narrow spread of final counts.

Insights:
The stability of the distribution suggests that the number of right-sided turtles does not fluctuate significantly across runs.
The absence of outliers indicates uniform model behavior for this category.

Boxplot 2: Distribution of Left-Sided Turtles at Final Step

Key Elements:
Box (Blue Rectangle): Represents the IQR for left-sided turtles, spanning from approximately 800 (25th percentile) to 875 (75th percentile).
Median (Line Inside the Box): The median count is around 850, showing that half of the runs ended with this value or higher.
Whiskers: Extend to approximately 750 (minimum typical value) and 950 (maximum typical value), covering the full range of typical outcomes.
Outliers: No outliers are visible, indicating a consistent pattern for this category.

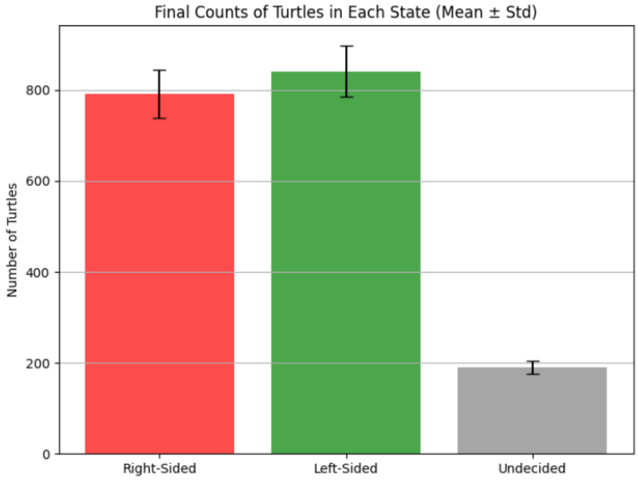
Observations:
Median: The left-sided turtles exhibit a slightly higher median than the right-sided turtles.
IQR: A wider IQR compared to the right-sided turtles suggests greater variability in the final counts.

Insights:
The broader spread in this boxplot indicates that left-sided turtles are more influenced by stochastic dynamics in the model.
The lack of outliers implies robustness in the final counts, with no extreme deviations.

Overall Insights

Variability Across Runs:
Both distributions show moderate variability, with slightly more spread observed for left-sided turtles. The absence of outliers in both plots highlights consistent behavior in the model's dynamics for these categories.

Comparison of Distributions:
Left-sided turtles have a slightly higher median and IQR, suggesting they are more dynamic in response to the model's parameters.



Key Elements of the Chart

Bars (Mean Counts)

Right Sided (First Bar): The height of the bar shows the mean number of turtles that remained right sided at the final step. This is the second highest bar, indicating that right sided turtles constituted the second largest group on average by the end of the simulation.

Left Sided (Second Bar): The height of the bar shows the mean number of turtles that remained left sided at the final step. This is the highest bar, indicating that left sided turtles constituted the largest group on average by the end of the simulation.

Undecided (Third Bar): Represents the mean number of turtles that remained undecided (neither right sided nor left sided) at the final step. This bar shows that a significant portion of the population remained non-voters at the final step.

Error Bars (Standard Deviation)

The error bars show the variability (± 1 standard deviation) in the final counts across all simulation runs:

Right Sided has relatively high variability in comparison to left sided, indicating that the number of right sided turtles at the final step fluctuates significantly between runs.

Left Sided has low variability, suggesting more consistent outcomes for left sided levels.

Susceptible shows the highest variability, reflecting the most fluctuation in the number of turtles that do not vote.

Insights

Voting Behavior Dynamics: A considerable number of undecided turtles suggests that the turtles undecided remained active in the network by the end of the simulation.

Variability in Outcomes: Runs showed high variability in the right sided population, low variability in left sided and most variability on undecided turtles, reflecting the stochastic nature of voting behavior in our model and showcasing undecided turtles generally change their opinions more easily.

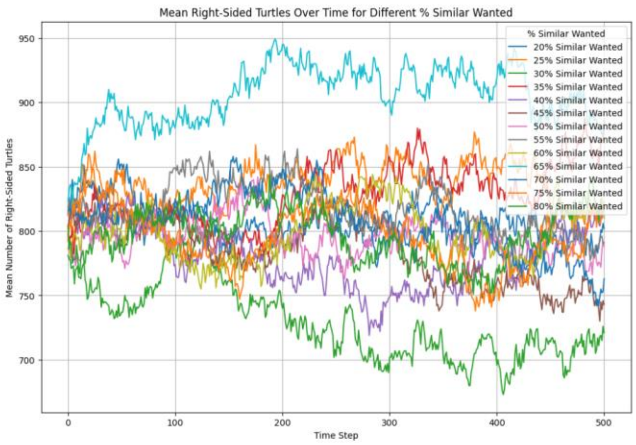
Real World Analogy

The high number of left sided turtles at the end of the simulation over multiple runs suggests that the voting leaning may change over time in Turkey.

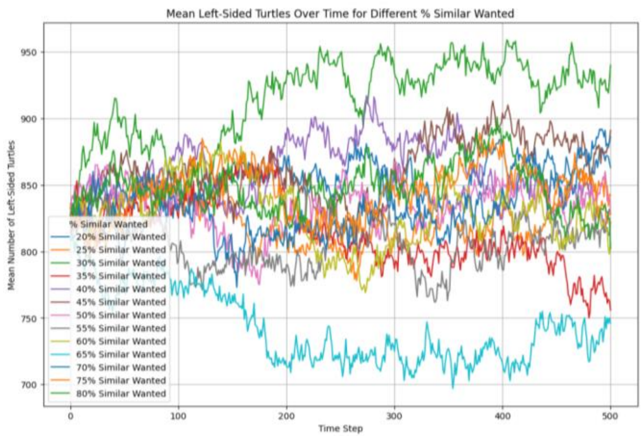
Sensitivity Analysis

Local Sensitivity Analysis: Explore small changes to individual parameters and their effects.

Right-Sided Turtles

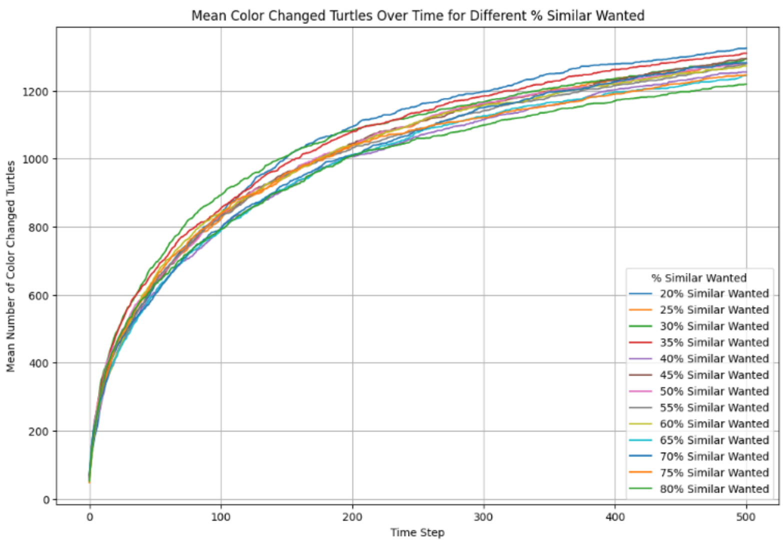


Left-Sided Turtles



Right-sided turtles remain in the range from 650 to 950 while the left-sided turtles remain in the range from 700 to 950. The variation in the mean number of right-sided turtles is decreasing as the similar wanted values approach the middle. This observation is the same for left-sided turtles too.

Color Changed Turtles



This graph shows how the mean number of color-changed turtles change over time with respect to different similar wanted values.

Early vs. Middle vs. Late Time Steps

Early (0–100): Most turtles are in a "baseline" state (few color-changed, decisions not yet made), so small parameter differences lead to big variations in how quickly changes begin.

Middle (100–300): Systems typically see a peak or at least a big wave of transitions/decisions, and you get a lot of variability. This is where you see the largest differences between lines for different thresholds.

Late (300–500): By this stage, systems tend to stabilize. Most turtles have either changed color, decided to remain, or found a "comfortable" location. Small changes in the threshold still matter, but the overall range of motion is narrower.

Variability (Run-to-Run Differences)

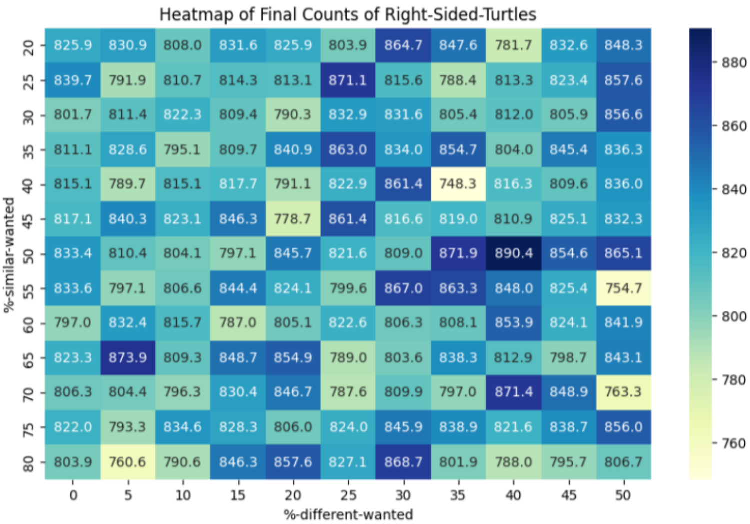
Even at a single value of "Similar Wanted," there can be considerable run-to-run noise. One run may have a wave of early color changes, another run might see them happen later. This is why lines can cross and re-cross.

Practical Interpretation

Sensitivity: Incrementally changing "% Similar Wanted" from, say, 50% to 55% can nudge the system into different spatial patterns or color-change cascades.

Emergent Patterns: The lines suggest there are tipping points. Around certain thresholds, we suddenly see big jumps in color changes or shifts in how many remain undecided.

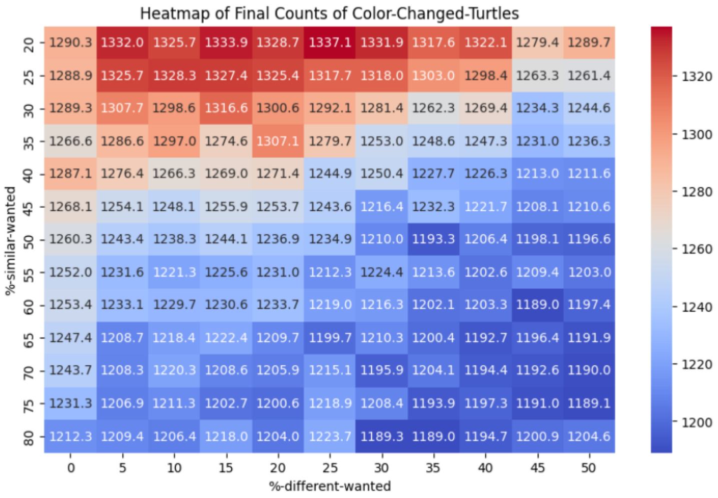
Global Sensitivity Analysis



This heatmap visualizes the combined effect of %-similar-wanted (y-axis) and %-different-wanted (x-axis) on the mean number of right-sided turtles at the final step of the simulation. The color intensity represents the average number of infected turtles, with red indicating higher right-sided votes and blue indicating lower levels.

High similar-wanted: When the similar-wanted is high (e.g., %80, the number of right-sided turtles remains high across middle different wanted values. Even with a high different wanted (e.g., 50%, right-sided turtles persist due to the rapid interactions in the model.

Low similar-wanted: When the similar-wanted is low (e.g., %20, the number of right-sided turtles is increasing and decreasing as the different wanted is increasing, especially it is the most at middle values of different wanted.

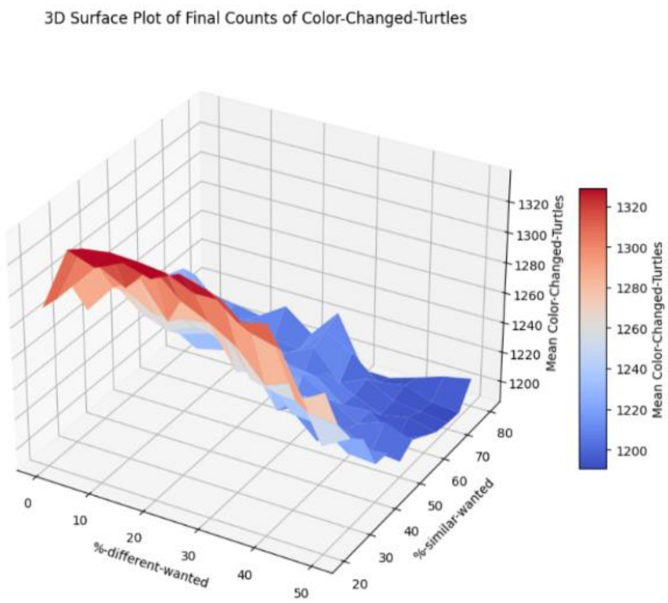


Other than the first heatmap, the color intensity in this one represents the average number of color changed turtles, with red indicating higher changing ideas and blue indicating lower levels.

High similar-wanted: When the similar-wanted is high (e.g., %80, the number of right-sided turtles remains low across middle different wanted values. Even with a high different wanted (e.g., 50%, right-sided turtles remains the same with lowest value of different wanted due to the rapid interactions in the model.

Low similar-wanted: When the similar-wanted is low (e.g., %20, the number of right-sided turtles is increasing and decreasing as the different wanted is increasing, especially it is the most at middle values of different wanted.

In general, the peak points in the map are located at the peak values of both parameters, as both are increasing the number of color changed turtles are decreasing since the interactions between agents hit bottom while both parameters are decreasing the number of color changed turtles are increasing since the movement is increasing resulting in new interactions and changing ideas over all.



This heatmap explains the changes in the final counts of color changed turtles with respect to both of similar wanted and different wanted parameters.

High vs. Low "% Similar Wanted"

High % Similar Wanted (e.g., 60–80%): In the right-rear region of the plot (larger values on the "% similar wanted" axis), the surface often transitions to cooler colors (blue), corresponding to fewer total color changes.

Interpretation: When agents have a very high requirement for neighbors to be like them, they may settle more quickly once they find a sufficiently homogeneous spot. This can result in less overall flipping of color because the population partitions into stable pockets, lowering the final count of color changes.

Low % Similar Wanted (e.g., 0–20%): On the left side of the "similar wanted" axis, the surface is more elevated (red/orange), corresponding to more color changes.

Interpretation: With a low requirement for similarity, agents are more flexible, potentially switching color easily to adapt or mixing with diverse neighbors. This can cause frequent flipping before the system settles, driving up the total number of color changes over time.

High vs. Low "% Different Wanted"

High % Different Wanted (e.g., 60–80%): Toward the far edge of the "% different wanted" axis, we again see a shift (often toward bluer or mid-range values).

Interpretation: If agents demand a large fraction of neighbors to be different, they might cluster in areas that fulfill that diversity requirement relatively quickly—or move away from places that are too uniform. This can reduce prolonged flipping once they've found that balanced mixture.

Low % Different Wanted (e.g., 0–20%): Near zero on the "% different wanted" axis, you tend to see the redder/higher region of the surface.

Interpretation: With low tolerance or desire for diversity, some agents keep searching for more homogenous pockets (or keep flipping color trying to achieve a neighborhood that's mostly similar). In practice, this can lead to more repeated color changes as the network tries to resolve tensions between similarity/difference preferences.

Transition Zones & Steep Gradients

In the middle ranges of both axes (e.g., "similar wanted" ~30–50% and "different wanted" ~30–50%), the surface sometimes exhibits sharp transitions or more pronounced ridges/valleys.

Meaning: These are "tipping points" where small changes in either %Similar or %Different Wanted can abruptly alter how easily the turtles find a stable color arrangement. One small tweak in these midzones might spark a cascade of color changes or, conversely, dampen it.

Critical Regions

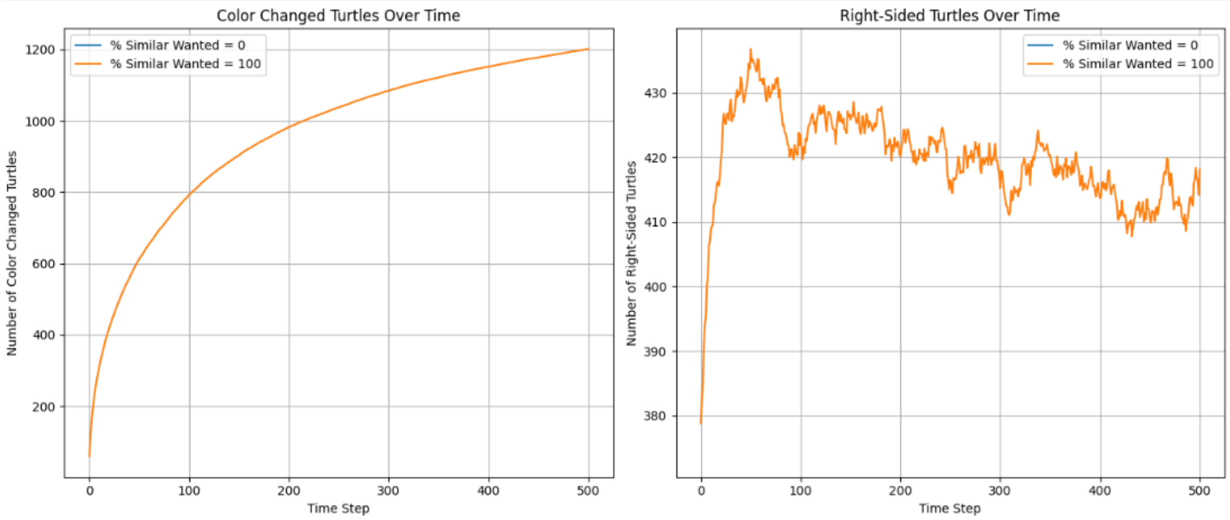
High % Similar Wanted & High % Different Wanted (top-right corner): Because turtles want both a high similarity and a high diversity in their neighborhoods (which can be contradictory), the system may find a delicate balance that leads to fewer total color changes—but only after initial turbulence.

Low % Similar Wanted & Low % Different Wanted (bottom-left corner): Agents are fairly indifferent—they don't need many similar neighbors nor many different neighbors. Surprisingly, this can generate a lot of flipping, as there's no strong "pull" to stabilize one color arrangement over another.

Practical / Policy Analogy

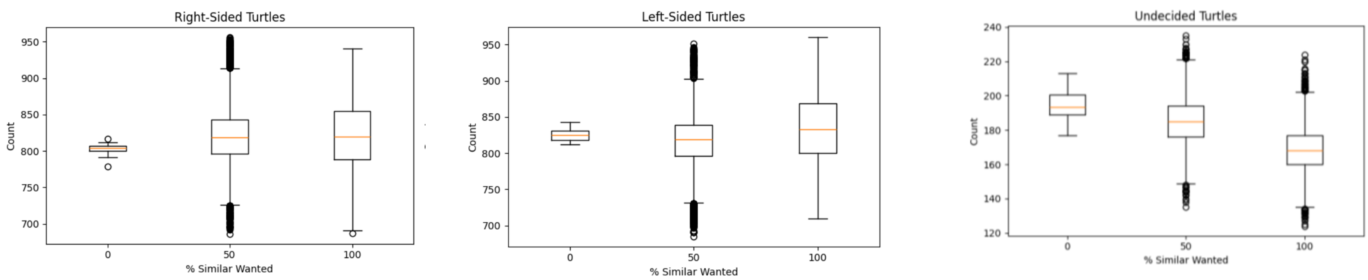
Midrange Values create volatile zones, where small parameter nudges (like a slight increase in "different wanted" or "similar wanted") can abruptly change how many turtles ultimately flip their color.

Robustness Analysis



Extreme Values: For this scenario they are 0 and 100. The model does not work for a 0 value of similar wanted since there is no reason to move thus to communicate to the other agents as all of the turtles remain happy.

Highest similar wanted: The number of right-sided turtles increases suddenly (at the early stage 0 100) and then decreases as time goes by. However, the number of color changed turtles increases consistently. This increase is permanent while its velocity decreases as the interactions between opposite sides decrease with clustered groups of opinions in the model.



Right-Sided Turtles

% Similar Wanted = 0

Counts cluster around the high 700s to low 800s, with a narrow IQR.

Median is near 800, suggesting consistent formation of right-sided turtles, even when turtles do not require similar neighbors.

Outliers are minimal, implying stable outcomes with no-similarity constraint.

% Similar Wanted = 50

The box is noticeably wider, indicating higher variability.

Median remains near 800, but whiskers extend substantially in both directions.

Multiple outliers above 900 and below 700 reflect runs where right-sided grouping either became dominant or was suppressed.

% Similar Wanted = 100

Median is somewhat lower (mid- to high-700s) than at 0% or 50%.

The IQR and whiskers suggest that while many runs settle around the 750–800 range, there are both upper outliers (~950) and lower outliers (~700).

This indicates that demanding full similarity sometimes yields either very strong right-sided alignment or a drop in right-sided turtles (perhaps due to constraints on forming a large homogeneous group).

Left-Sided Turtles

% Similar Wanted = 0

Like the right-sided case at 0%, the median is around the 800s, with a narrow IQR and few outliers.

Results are highly consistent, implying most runs converge on a similar left-sided count when no similarity requirement is imposed.

% Similar Wanted = 50

The distribution becomes quite spread out, with many outliers at both extremes (below 700 and above 900).

Median is around the mid-700s, but the high whiskers and numerous outliers show the system can swing widely between runs—some cluster strongly to the left, others less so.

% Similar Wanted = 100

The median is around 760–770.

A high number of outliers extends well into the 900+ range, and a few dip below 700.

This indicates that under the strictest similarity requirements, some runs yield large left-aligned majorities, while others fail to form large contiguous left-side clusters.

Undecided Turtles

% Similar Wanted = 0

The median is around 180–190, with an IQR from ~160 to ~200.

A moderate number remain "undecided" when no similarity is required; presumably they do not join left or right or change color.

Few outliers, suggesting consistent behavior across runs.

% Similar Wanted = 50

The distribution spreads out further, median around 170, but whiskers range from ~120 up to around 210.

Many outliers exist above 220, indicating runs in which a large subset of turtles never resolved their final affiliation.

This highlights that half-similarity constraints lead to some unpredictability in final states.

% Similar Wanted = 100

Median shifts down to the 140–150 range, with a wide IQR and numerous outliers.

The presence of outliers near 100 or lower suggests that under strict homophily, more turtles ultimately pick a side or change color, leaving fewer truly "undecided."

Conversely, the high outliers near 240 indicate runs in which too-strict similarity demands cause many turtles to remain stuck in the undecided state.

Robustness Analysis

Extreme Scenarios Chosen

% Similar Wanted = 0: Represents the minimal neighbor-similarity constraint (no preference for similar neighbors).

% Similar Wanted = 100: Represents the strictest possible homophily (neighbors must be identical).

% Similar Wanted = 50: Midpoint scenario revealing partial preference for similar neighbors.

Robustness vs. Parameter Ranges

At 0% similarity required, outcomes are relatively stable (narrow IQR, few outliers).

This suggests the model's baseline tendencies (e.g., initial conditions, random mixing) dominate.

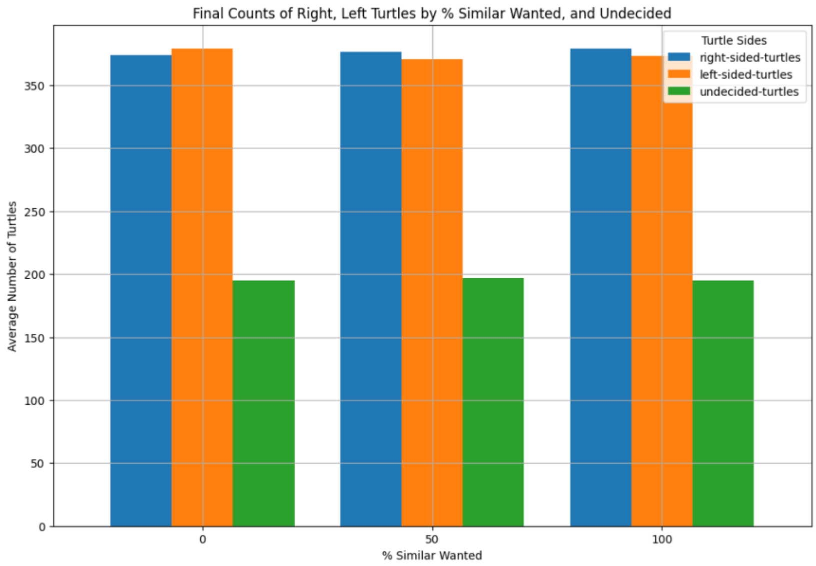
At 100% similarity required, we see significantly more variability and more outliers in several categories, revealing that runs can diverge substantially if turtles' strict demands for similar neighbors lead to large homogeneous clusters in some runs but not in others. 50% similarity can produce the widest distributions in some categories (e.g., Right-Sided, Left-Sided, and especially Color-Changed Turtles), indicating that a partial preference can amplify stochastic effects.

Rationale for Extremes and Insights

Worst-Case Conditions: Demanding 100% similarity or none at all tests whether the model remains consistent (few outliers) or if it diverges unpredictably (many outliers).
Observing Theoretical Limits: By toggling from 0% to 100% similarity, we illuminate how strong homophily or its absence reshapes the distribution of turtle states.

Overall, the results show that with moderate (50%) or strong (100%) similarity constraints, certain states (e.g., color-changed, left- or right-sided) can dominate or fluctuate more widely, whereas with 0% constraint, the system often remains in a narrower band of possible outcomes as the model does not work in the lowest similar wanted since all turtles remain the same.

Distribution of Votes at Last Step in Extreme Points



The final counts of right-sided left-sided and undecided turtles does not change with respect to extreme values of similar wanted. There is only one change for the value 0, where the interactions did not happen as all of the turtles in the model remain happy with a %0 of similar wanted.

Key Takeaways

- Right- and Left-Sided Turtles: Show a narrow spread at 0% and large variability at 50% and 100%.
- Color-Changed Turtles: Extremely low counts at 0%, then a marked jump once similarity constraints kick in (especially at 50%).
- Undecided Turtles: Moderately stable when 0% similarity is required; become more variable at higher constraints.
- Robustness: The model is “predictable” under no constraints (0%) -which is stemmed from the model’s not working at 0%- but can exhibit large swings and many outliers when moderate (50%) or total (100%) homophily requirements are enforced.

These observations illustrate that increasing similarity requirements magnifies heterogeneity in outcomes and introduces outliers—a hallmark of less “robust” behavior under more stringent conditions.

With these insights, we have decided to keep our range of similar wanted and different wanted scales from 0 to 80, for the sake of the model’s robustness. Also, we decided to select similar wanted and different wanted percentages such that they complete each other to 100 at max, resulting in more accurate solutions.

Validation and Verification

Verification

The model undergoes visual testing by observing agent behavior tick by tick. After setup, we verify that agents are correctly placed on valid patches. We monitor their movement patterns and color changes to ensure they follow the defined political spectrum thresholds. Real-time monitors track key metrics like percent-similar and percent-unhappy.

Parameter Testing: We conduct systematic parameter sweeps by varying % Similar Wanted from 0 to 100 to test segregation patterns. Multiple runs with different random seeds verify reproducibility. Consistent patterns across runs indicate proper model behavior, while unexpected variations prompt code review.

Code-Level Debugging: Print statements track runtime behavior, particularly in the political persuasion and patch-finding procedures. We verify that persuasiveness influences work correctly and that agents avoid invalid patches while relocating.

Component Testing: Individual model components are tested in isolation. For example, we disable movement to test persuasion mechanics independently or set extreme similarity preferences to verify clustering behavior. External event responses are tested by enabling specific campaign effects.

Validation Against Theory: Results are compared against expected Schelling segregation patterns. We verify that moderate similarity thresholds produce appropriate clustering, and that political persuasion mechanics create plausible opinion dynamics.

Comprehensive Verification: The testing approach combines visual checks, parameter testing, code debugging, component isolation, and theoretical validation. This ensures the model accurately represents both segregation dynamics and political persuasion mechanisms.

Validation

The model outputs are compared against expected patterns of political polarization and social clustering, such as those described by Schelling's segregation models. By reflecting Turkish demographic and voting data from the 2023 elections, the model aims to ensure alignment with actual regional political dynamics and shifts.

Assumptions: The model assumes linear relationships in persuasion and susceptibility, which simplifies complex human behaviors. It uses static and randomized parameters for initial conditions, like persuasiveness and susceptibility, to reflect variability but does not account for changes over time or external influences outside of political campaigns.

Limitations: Real-world complexities like economic constraints, cultural influences, and historical contexts are not included. The relocation dynamics are simplified to random movements within a radius, not reflecting real-life constraints or decision-making processes. The focus is solely on political spectrums without integrating multi-dimensional social factors.

Discussion

Results Interpretation:

The model successfully demonstrates the interplay between political preferences, social influence, and regional variations in Turkey's political landscape. Key findings include the formation of polarized clusters and the role of external political campaigns in influencing voter dynamics. The results align with project objectives, such as illustrating regional political leanings and simulating shifts caused by social and environmental factors. The consistency observed across simulations highlights the robustness of the model in representing real-world political phenomena while allowing for insightful scenario analysis.

Model Strengths:

One of the most compelling strengths of this model is its ability to capture both spatial segregation dynamics and political persuasion in a single framework, thereby offering a more holistic view of social clustering and opinion shift than simpler segregation models. Specifically, it integrates Schelling's logic of neighbor preferences and NetLogo's agent-based design, enabling the observation of spontaneous clustering and reorganization as agents respond to dissatisfaction with their local mix of neighbors. Additionally, the explicit modeling of political persuasion—including parameters like persuasiveness and susceptibility—provides a dimension of ideological drift that enhances realism, reflecting scenarios in which influential voices within a population sway less-convinced individuals. The presence of external campaign events further heightens this model's realism by allowing macroscopic shocks to drive unexpected shifts in opinions, thereby simulating real-world phenomena such as election cycles, public events, or significant political campaigns. Overall, its integrated design and adjustable parameters make the model versatile for exploring a wide range of social and political dynamics.

Model Limitations:

Despite these strengths, the model does carry certain inherent limitations that must be considered when interpreting results. First, it relies heavily on simplified assumptions about human behavior and social influence, such as the linear relationship between persuasiveness and susceptibility and the notion that relocation depends solely on the proportion of similar or different neighbors. Real-world dynamics often include more complex social networks, historical contexts, and multiple overlapping identities that are not fully captured here. Second, because agents move randomly within a specified radius until they find a suitable patch, the path-dependent nature of real-world relocation decisions is underrepresented. This can sometimes yield rapid or oversimplified transitions in the simulation. Additionally, the model focuses on color-coded political spectrums and does not directly address other major social factors—like economic constraints or cultural ties—that might influence both housing decisions and ideological shifts. These simplifications, while necessary for tractability, mean the model is not fully predictive and must be viewed primarily as a conceptual and illustrative tool.

Suggestions for Improvement:

The following refinements could enhance the model's realism and applicability:

Adding variables such as income levels and cultural ties could provide a more holistic view of voting behavior.
Allowing these parameters to evolve over time could better reflect real-world changes in agent behavior.
Replace random movement with a path-dependent decision-making algorithm that considers proximity to resources, infrastructure, or social networks.
Include network-based interactions, reflecting influence from family, peers, or media, to capture more nuanced social dynamics.
Expand beyond political spectrums to incorporate other social dimensions, such as environmental attitudes or economic priorities, for broader applicability.

Conclusion

The simulation effectively replicates patterns of political polarization and social clustering, providing a conceptual understanding of how individual preferences and interactions shape societal dynamics. The inclusion of realistic parameters, such as persuasiveness and susceptibility, enhances the model's ability to mimic real-world behaviors. The results emphasize the emergence of stable clusters and the impact of political campaigns on moderates, offering insights into potential ideological shifts within Turkey.

The model integrates spatial dynamics, agent-based interactions, and external events to create a comprehensive framework for studying political polarization. It goes beyond traditional segregation models by incorporating persuasion dynamics and regional variations, providing a multi-dimensional perspective on societal behaviors. This framework offers valuable insights for political science and social studies, making it a versatile tool for analyzing the effects of campaigns and demographic shifts on polarization.

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