Simulation of Social Dynamics: The spreading of misinformation

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An article usually includes an abstract, a concise summary of the work covered at length in the main body of the article.

Contributions: Project idea conceived by E. Nocet–Bibois. Simulation model concept conceived by A. von Kaenel, E. Nocet–Bibois and L. Fu. Programming by A. von Kaenel and E. Nocet–Bibois, assisting programming by L. Fu. Document formatting by L. Fu. Introduction written by E. Filios. Method written by L. Fu. Results written by L. Fu and E. Nocet–Bibois. Discussion and conclusion written by L. Fu, H. Ge.

CONTENTS

I. INTRODUCTION

A. Background

With the increasing incorporation of the internet in the average individual's life, digital social interaction has become more common. With how socializing was done before, being more so in person and spatially limited, the option to socialize digitally has become more popular due to its accessibility while retaining factors of socializing. Individuals therefore split their time spent on these two options.

Plumridge (2020) talked about socialization in person vs. online and how choosing the online interaction "may lead to a degeneration of the social skills necessary to engage in real life interactions" [1]. On the other hand, other authors argue that online interaction has many advantages: flexible in nature, easy connectivity, increases the efficiency and productivity throughout different online tools. Examples for the benefits of online interactions were visible during the Covid-19 pandemic times, where it was indispensable, e.g for mental health professional to get in touch with remote people, as described by Cheng et. al (2020). [2].

In 2022, 63.1 percent of the total population was internet users, out of which 59 percent of the people were social media users, according to Statista. [3].

In 2020, Lieberman & Schroeder [4] studied the differences between online and offline interaction and how they influence the social outcomes. They identified four differences: fewer nonverbal cues, greater anonymity, more opportunity to form new social ties and bolster weak ties and wider dissemination of information. In our project, we will focus on the latter.

As we know, in online interaction there is no real limit when it comes to the audience size, whilst in the offline interaction, there is usually a limit in the size of one's audience, such as the physical size of the room. It is much easier and accessible to share any content online than it is in the offline interaction. But this is where the problem comes and with it, our research questions: "How does information spreads faster?". The answer is obvious: online interaction, but "Which information spreads faster: true or false?".

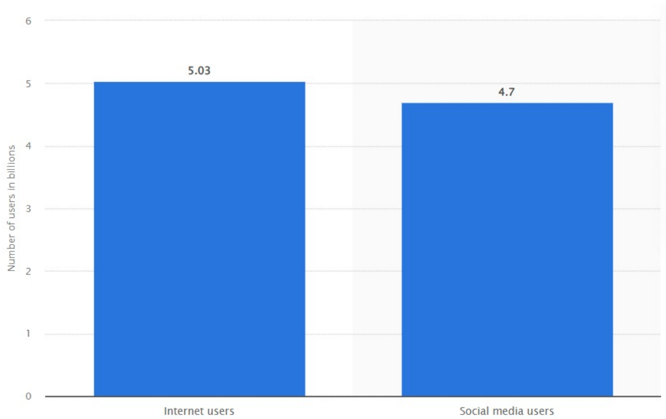


FIG. 1: Internet and social media users in July 2022, in billions.

Vosoughi, Roy & Aral (2018) [5] studied the diffusion of approximately 126000 true and false news shared on Twitter by almost 3 million people between 2006 and 2017. Their results showed that false information spreads "faster, farther, deeper and more broadly than the truth in all categories of information". The reason behind this is that false information is usually newer than true news, making people sharing it more.
Online interaction can either disrupt or enhance the offline communication. On one hand, digital technology can harm well-being and reduce sociality, therefore increasing loneliness. On the other hand, many connections that start online continue offline and online tools can provide support when offline interaction is impossible to achieve.

B. Project goal

The goal of the project is to simulate agents over time to see how their preferred social interaction would end up affecting the qualities of an individual. Different parameters can be used to differentiate between digital and physical interactions. For example, digital interactions can be subject to higher or lower amounts of stochasticity to represent the Internet's wide reach or respectively content suggestion algorithms that guide users to similar ideas.
Individual agents can be characterised by randomly initialised qualities such as: gender, age, socio-economical status, relationship status. Environmental changes could be regarding: the geographical location like a rural town or large city, ongoing politics in a country, cultural influence. Interactions between agents will be based on a stochastic process where two similar agents will be more or less likely to interact.
From different sources, we have found out that there is no perfect recipe for spreading information, but we can get the best from both of the two types of interactions: online and offline by balancing their usage in our everyday lives. Thus, our project goal is to analyze how information is spread faster and discover if, with simulated agents over time, we can get the same results as the discussed studies.

II. METHOD

A. Physical social interaction

The simulated society is represented by a matrix of agents, with each agent having a set of qualities and beliefs. These qualities affects the probability of an agent ending up believing the agent they are interacting with. The qualities are represented by a number in the interval $q \in [0, 1]$, and the belief is represented by a boolean or 0 or 1.
When engaging in a social interaction, the agent looks at the 8 nearest neighbours, the Moor neighbours, and interacts with all of them. The two agents then have a random chance at convincing the other agent regarding their beliefs, who then inherits some amount from the one that convinced them. As mentioned previously, the qualities of each agent affects the likelihood of believing another agent, weighting so that they are more likely to be convinced by agents with similar qualities. Additionally each agents qualities change over time to approach the mean of their neighbours qualities with which they share beliefs with.
This is then repeated for all individuals for that one time step synchronously so that in one time step, all interactions occur simultaneously, and the process is repeated for multiple time steps.

B. Digital social interaction

In order to show how a digital social interaction affects the matrix of agents, an adjacency matrix is used to connect agents regardless of their proximity. When two individuals are connected by the adjacency matrix they are able to interact in the same way as if they are interacting physically. The interaction process and results from interacting digitally are the same as the physical interaction, where the agent checks all possible interactions via the adjacency matrix and chooses to believe based on their qualities.
Engagement in social interaction by digital means occur separately from physical interactions, meaning that during a time step, an agent attempts to interact physically first, then digitally. Since in reality, digital interactions are more so an extension of than a replacement of physical interaction.

C. Additional parameters

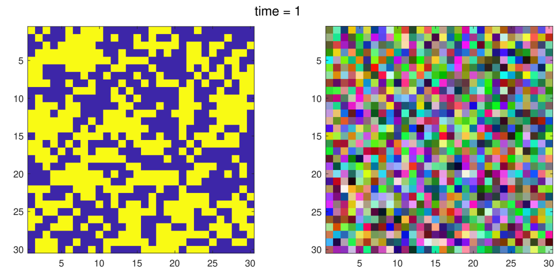
To add more depth to the simulation, more parameters can be included. The individual agent quality change can be predetermined via the probability of change in quality and the quantity of change. Individuals can also spontaneously change with a small probability, and the quantity of change here can also be predetermined. Lastly the quantity of belief obtained through conviction via social interaction can be parametrisized.

D. Graphical representation

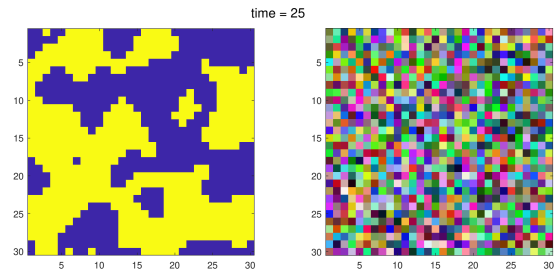
To visualize the simulated society, the matrix of agents is represented by a grid of coloured squares, the colour of which are determined by the beliefs associated with the corresponding agent. Additionally, the qualities of each agent can be displayed, which by using three quality variables $\{q_1, q_2, q_3\}$ and corresponding the variable values to an RGB scale, can be graphed out in multi-colour instead of binary.

E. The spreading of information

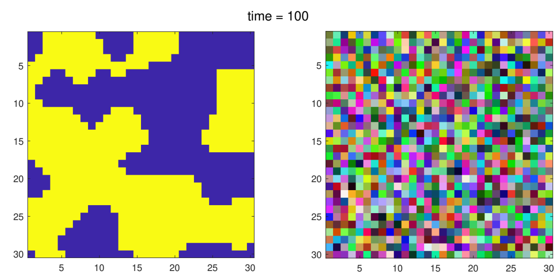
The method to see information spreading across the agent matrix is via the graphically represented grid of beliefs that are displayed binarily. As either beliefs end up being preferred by the agents, it will gradually spread across the lattice. By changing parameters, different patterns of behaviours of information passing may be observed.



(a) $t = 1$



(b) $t = 25$



(c) $t = 100$

FIG. 2: The spreading of beliefs in a 100 by 100 lattice of agents. The time passed is (a) $t = 1$, (b) $t = 25$ and (c) $t = 100$. As time passes, the regions for the beliefs become increasingly more defined.

III. RESULTS

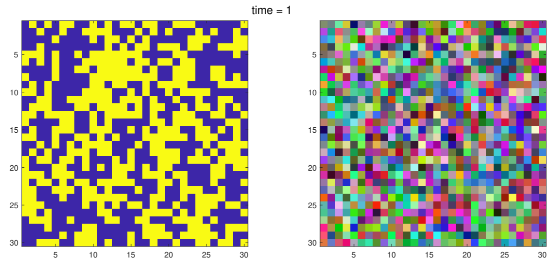
A. Only physical interactions

For a lattice of 100 by 100 agents and each agent consisting of a vector of qualities and a belief $\{q_1, q_2, q_3, belief\}$ the results of graphs for figure 2 were generated. The values of each agents variables were randomly selected and subsequent interactions with their neighbours are calculated for each time step. As can be observed in the right figure of the figure sets in figure 2, the quality of each individual remains static over the process, but the regions approach a stable state as time passes.

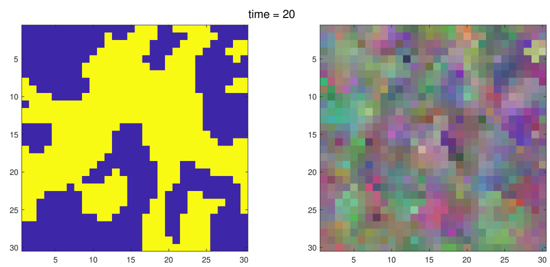
By Including some more parameters as described in the section about additional parameters, the qualities of the agents in the lattice are allowed to vary and can be graphed out continuously along with the belief. For the results shown in figure 3, parameters were as follows:

1. Quantity of change of quality from neighbours $\Delta Q = 0.3$
2. Probability of quality change $P_q = 0.3$
3. Quantity of spontaneous quality change $\Delta Q_s = 0.2$
4. Probability of spontaneous quality change $P_s = 0.001$
5. Probability of belief change based on neighbours $P_b = 0.3$

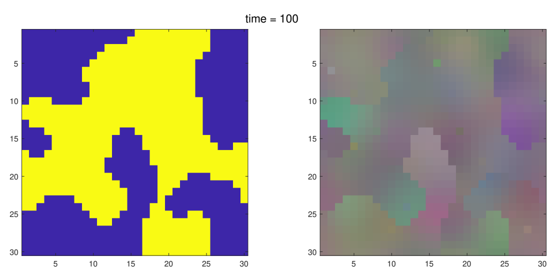
Further experimenting with parameters for physical interactions only did not display any new behaviour from the parameters stated above in terms of belief. However the qualities of the agents instead begin shifting to align with the beliefs.



(a) $t = 1$



(b) $t = 20$



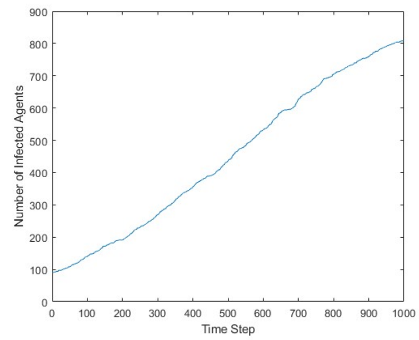
(c) $t = 100$

FIG. 3: The spread of beliefs are graphed on the left side, while the qualities of the agents are shown on the right. The graph eventually stabilizes and finds an equilibrium point.

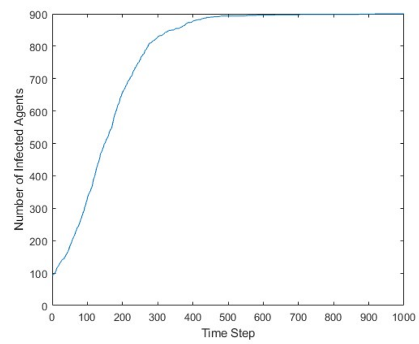
B. Only digital interactions

In this section we study the case where we allow interactions between agents over the whole domain, with higher likelihood of connecting like-minded people, but still preserving some probability that an agent will choose to interact with someone they share little with.

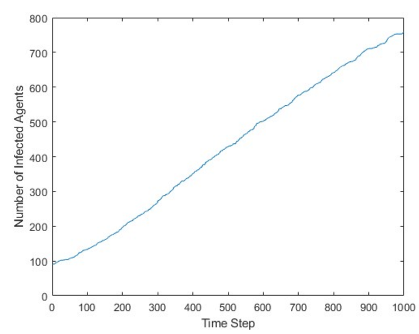
Then, we look at the evolution from a case where a certain fraction of the population is "infected" by a false belief, according to the following rules: a false belief is only transmitted between interacting people, and according to the sensitivity of each agent to a false information (representing the attraction that one can have for novelty).



(a) Case $p_{\text{one-sided}} = 0$



(b) Case $p_{\text{one-sided}} = 0.5$



(c) Case $p_{\text{one-sided}} = 1$

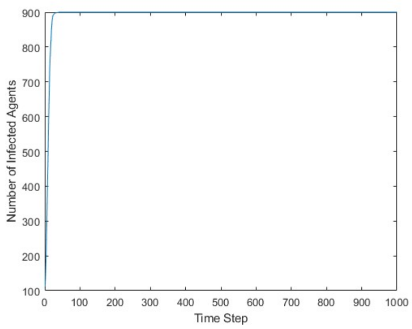
FIG. 4: Spread of misinformation over time in different cases of one-sided relations probability (with $N = 900$, $T = 10^3$, $n_{\text{qualities}} = 3$, $p_{\text{like-minded}} = 0.8$, $f_{\text{infected}} = 0.1$)

1. *Effect of one-sided interactions*

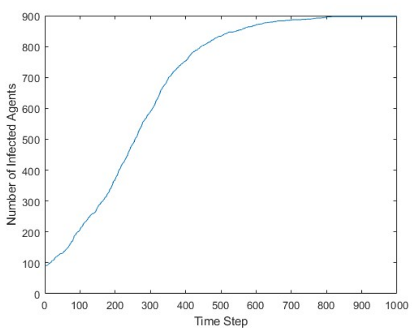
An important feature of digital social networks is the importance of one-way relationships: the same person can be followed by a large number of people, giving them an influence that would not be possible in real life. This potentially increases the speed of transmission of such a person's beliefs.

2. *Effect of profile suggestion*

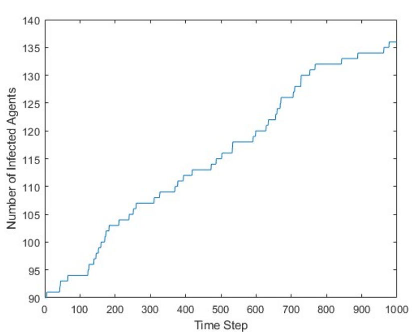
Social interactions on digital networks have the particularity of being largely governed by content suggestion algorithms that direct users to other agents with more or less different characteristics. We can thus test the cases of an algorithm with a high level of conformity versus a high level of openness to new profiles, by varying the probability that an agent interacts with someone other-minded.



(a) Case $p_{\text{like-minded}} = 0$



(b) Case $p_{\text{like-minded}} = 0.7$



(c) Case $p_{\text{like-minded}} = 1$

FIG. 5: Spread of misinformation over time in different cases of interaction preferences (with $N = 900$, $T = 10^3$, $n_{\text{qualities}} = 3$, $p_{\text{one-sided}} = 0.5$, $f_{\text{infected}} = 0.1$)

3. *Effect of novelty appeal*

However, if the case of one-way relationships and openness to others says something about the transmission of beliefs in digital versus real-life networks, it says nothing specifically about the transmission of false versus true beliefs. In this respect, we can note a psychological factor, namely the attraction of each agent to novelty. The objective here is to test the hypothesis put forward in the article [6] that shows that bad information spreads faster than true information, and suggests that the reason for this is our attraction to new information. Indeed, there is nothing more new and seemingly groundbreaking than information that is completely out of line with what we know about the world.

C. Both real-life and digital interactions

IV. DISCUSSION

A. Feasibility of results

1. *Purely physical interactions*

In the results where only physical contact is considered it can be observed that a clear border between the two beliefs is created, which similarly is reflected in the quality of the agents. The amount of spontaneous change introduced in the parameters was not enough in this case to break the stabilized environment. Even by heavily altering the parameters, the spontaneous quality changes and increased likelihood of belief change, the final stable pattern was not in any way broken.
It is possible that heavy stochastic change by quality is not enough to change the belief of agents due to how changing beliefs work. The probability of changing beliefs is based on how similar neighbours are to an agent in terms of quality. When a nearby agent is spontaneously altered in quality, it does not necessarily fall in line with the qualities of its neighbours, and therefore it is not likely to cause a change in belief. Even an agent that is subjected to the stochastic quality change does not necessarily change their beliefs, since the change in belief is based on their neighbours, and the passing of beliefs are by similarity of quality.
It seems that, instead of qualities determining what an agent chooses to believe, it is the beliefs an agent has that shapes their qualities. Even through heavy changes in quality, it is unable to change the beliefs of others.

How does this compare to reality? In an article about how an individuals beliefs affects their personality it was concluded that beliefs governed how individuals package and interpret their experiences, thus altering how those experiences would shape their personality. Two individuals experiencing the same thing but with different beliefs would naturally extract different values from the event. This therefore seem to align with results of simulation where the belief is the core value of an agent, while the qualities revolve around their own beliefs and the qualities of agents around them.

2. Only digital interactions

With agents more in touch with people who hold other ideas more often, the spread of disinformation is effectively curbed. Indeed, in the digital world the voices of a few are amplified, and with the formation of information cocoons that make everyone prefer to stay in the stratosphere of people who hold the same opinions as they do, the more disinformation will get spread. And as we can see from the results, even if a small number of people exist to reject the phenomenon of open-mindedness, it will lead to the eventual spread of disinformation. So in the digital world, reducing the reliance on homogenized information and push algorithms of social media helps people to get real information.

3. Physical and digital interactions combined

B. Areas of further research

We can try to explore what effect the disinformation propagated in the digital world has in the process of opinion formation in the real world.

To describe the dynamics of multiple systems interacting with each other, we consider a multilayer network with 2 layers representing the different relationships between the agents. The dynamics of opinion formation is considered in layer A, which is referred to as the opinion layer. In layer B, the dynamics of information or disinformation propagation in an online social system is studied, which follows the classical SIR propagation model and is referred to as the information layer.

In layer A, each node may be in one of 2 states: the (+) opinion state or the (-) opinion state. These two states can be transformed into each other, on the one hand by the influence of neighbors and, on the other hand, each node has a certain chance to change its mind spontaneously (implemented with a noisy voter model). The speed of spontaneous transformation of these two states is denoted by v; the degree to which a node is influenced by its neighbors is denoted by h.

Assuming that the dynamic process of the layer B network evolves faster than that of the layer A, i.e., the update rate of the voting layer is much smaller than that of the message layer, the dynamics of the layer B network evolves to a stable or terminal state whenever the state of the layer A network is updated. Therefore, for layer A, only the final situation of message diffusion in layer B is affected.

V. CONCLUSION

Appendix A: Appendix title test

[1] N. Plumridge, Communication: Online vs. face-to-face interactions, (2020).

[2] P. C. et al, Covid-19 epidemic peer support and crisis intervention via social media, (2020).

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[5] R. D. . A. S. Vosoughi, S., The spread of true and false news online., (2018).

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[7] N. D. Birell and P. C. W. Davies, *Quantum Fields in Curved Space* (Cambridge University Press, 1982).

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