

A Dynamical Model of Social Movements on Social Media

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1 Abstract

This paper explores a model of the progression of social movements on social media. Social movements influence our everyday lives and can explain many sociological phenomena [4]. They are necessary to incite change within a society. With the rise of social media, human interactions have evolved and can be analyzed in new ways [7]. Using a mathematical SEIR model, we seek to calculate the number of people actively participating in a movement, being aware of it, and not knowing about it over a time span of several weeks. With a few assumptions, it is possible to analyze the parameters important to the spread of social movements on social media. Looking at specific cases while keeping the rest of the parameters constant, we can observe how they influence the death or continuation of social movements.

2 Introduction

Social networks have become a crucial part of society and open a window to understanding many phenomena such as herd mentality and factors which drive people towards participation in social movements [4]. Opinions, values, and grievances are often not enough to induce meaningful actions. Connections to people participating in a social movement are generally needed to drive people towards action [12]. Hence, it is reasonable to assume that affiliation with a social movement will spread through the population similarly to how a virus might.

Social movements are a sociological concept which is defined as networks of interactions between different individuals, groups and organizations, who are engaged in political or cultural conflicts, on the basis of a shared collective identity. The important aspects that need to be considered when defining the dynamics of a social movement are as follows:

- It needs to be a network based on informal interactions between groups and/or organisations and individuals.

- It needs to contain a collective solidarity and shared beliefs.
- It needs to engage in conflicts, cultural or political, and promote or dispute social change.
- For the majority of it, the action needs to be outside of routine and institutional procedures of social life.

Thanks to the broad definition of these aspects, the concept can be adapted to specific examples. If, for example, one study focuses on a global anti-systemic social movement then another will focus on a social movement supporting a local system and opposing changes to it. [3]

With the recent emergence of social media networks, the studies of social movements have evolved again, prompting further inquiries on the topic[8].

Many studies have started to compare how movements founded upon social media compare to those in the past that weren't[7]. For example, a transnational movement in Italy was analyzed to see how digital media like Facebook was used by activists to spread their message, considering the number of posts, likes and comments over the years [11].

Other studies looked at international movements. For example, a study was done on the *Black Lives Matter* movement and considered multiple social media platforms and the level of engagement of accounts. This study also discussed the limitations of social media. On one hand, traditional forms of organization still play an important role to sustain and build a movement. On the other hand, through the accessibility of social media, it is hard to maintain the actual goal and values of a movement, since many people can participate who might have different goals in mind. It is also easier for individuals to contradict the movement online by spreading opposing messages. However, the benefits of social media outweigh the costs, as it allows for a bigger scaling of social movements and a broader audience can be reached. [10]

Using mathematical models, we aim to gain a deeper understanding of how social movements progress with time through social media and to determine if we can observe a pattern between social movements and various parameters. Specifically, we hope to find which parameters and what values are necessary for a social movement to spread and how can they be used as tools in order to spread a message.

3 Methods

We relate our model (Figure 1, Equation 1) to a type of SEIR disease model where $I(t)$ is the number of infected individuals who are able to spread the disease to $S(t)$, which is the number of susceptible people. In our case, this would mean people actively engaged in the movement would be exposing social media users through posts. $E(t)$ acts as the exposed population: those who have come in contact with the disease or, in our case, those who have in come contact with the social movement by seeing social media posts about it, but who are

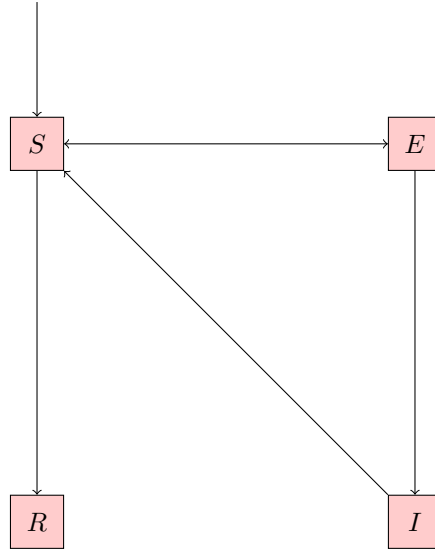


Figure 1: A diagram of the model

not yet actively involved. Similarly to how exposed individuals have a chance of becoming infected or going back to being susceptible: in our model, those who are exposed to the movement can decide if they wish to actively engage in it or go back to being a part of the susceptible, $S(t)$.

While no particular study relates the SEIR model to social movements and, in particular, social media, there are a few studies which involve analysing the use of social media alongside controlling the spread of diseases. Our model uses a similar analysis and techniques as some of these articles [5][1].

In our model, we do not have an $R(t)$, recovered members, because we want to focus on how efficiently people are joining the movement when exposed to social media, rather than focusing on those who are “recovering” from it. Moreover, our model also includes density dependence for Equation 1c, as $I(t)$ increases, that means there are more infected individuals, and thus there are fewer susceptible people to expose/infect, and thus $I'(t)$ would decrease depending on the population.

Before we start providing our equations, we need to clarify some assumptions that our model makes when taking the population and behavior of people into consideration.

3.1 Assumptions

Some of the assumptions we will make are listed here:

1. Everyone has equal access to social media, and our $S(t)$ only focuses on active social media users.

2. We won't consider a particular social media platform or consider different platforms as a parameter, but rather social media in general. Thus, we will not be considering specific social media algorithms.
3. We divide the population into two parts, labelling those who use social media as $S(t)$ and those who don't as $P(t)$.
4. We consider a closed population which means people who are not concerned about the movement will not share posts about it on social media.
5. The movement does not experience significant external interventions or disruptions. For example, there is not an opposing movement that is causing members to leave for the other.
6. The movement does not have significant internal divisions or conflicts that affect its growth and spread.
7. The platform used for the movement has a stable user base and does not experience significant changes in its user base or functionality.
8. The population of the community where the movement is taking place is relatively stable and does not experience significant demographic changes.
9. Social media overload can cause people to disengage from the movement and the platform.
10. The only way people can engage or become aware of the movement is through social media, particularly through posts that are being sent only by people already actively engaging in the movement, which we will call influencers.
11. After some time, posts tend to lose traction and no longer become trending. Thus, there can only exist a certain number of trending posts within any given period of time t . That is, $F(t)$ is a bounded function with maximum equal to k_8 .
12. Influencers are all equally influential online.
13. People are equally likely to see trending posts. Once they do, they immediately become "exposed" and then decide if they would like to join the movement or not.
14. People who leave the movement or decide not to join the movement after becoming exposed still use social media, so are then part of $S(t)$. We assume they just forget their recent exposure/involvement with the movement and are completely unaware of it until they are exposed another time.

3.2 Model Equations

Let N be the total population of the community where the social movement is taking place. Let $I(t)$ be the number of people engaged in the social movement at time t , let $E(t)$ be the number of social media users who are aware of the movement at time t , let $R(t)$ be the number of people recovering from using social media, meaning they stop using it completely, thus it's a particular subset of $P(t)$. Let $S(t)$ be the number of active social media users at time t , let $P(t)$ be the population of the community that does not use social media and let $F(t)$ be the number of trending posts related to the movement at time t .

$$\frac{dS}{dt} = k_6P(t) + k_2I(t) + k_5E(t) - k_3S(t)I(t) - k_7S(t) - k_4F(t)S(t) \quad (1a)$$

$$\frac{dE}{dt} = k_3I(t)S(t) + k_4F(t)S(t) - k_5E(t) - k_1E(t) \left[1 - \frac{I(t)}{S(t)}\right] \quad (1b)$$

$$\frac{dI}{dt} = k_1E(t) \left[1 - \frac{I(t)}{S(t)}\right] - k_2I(t) \quad (1c)$$

$$\frac{dR}{dt} = k_7S(t) \quad (1d)$$

where

$$P(t) = N - S(t) - E(t) - I(t) \quad (2a)$$

$$F(t) = k_8 \sqrt{\frac{I(t)}{N}} \quad (2b)$$

and where

- k_1 is the inverse of the minimum expected number of weeks it takes for a person to go from E to I . In other words the time it takes for an exposed individual to become actively involved;
- k_2 is the inverse of the expected number of weeks for an active member to lose interest and leave the movement;
- k_3 is the rate at which social media users become exposed and are aware of the movement (measured in $[1/(people \times weeks)]$);
- k_4 is the rate at which influencers promote the movement and thus make more people aware of the movement;
- k_5 is the inverse of the expected number of weeks an exposed person loses interest and disengages from the movement;

- k_6 is the rate at which the non-social media using population joins social media (measured in $[1/weeks]$);
- k_7 is the expected number of weeks for a person to leave the platform due to social media overload or other factors; and
- k_8 is the maximum number of trending posts that can be absorbed by a single person (measured in $[posts]$) (a phenomenon called the law of diminishing returns [2]).

Equation 1a describes most generally how the number of active social media users (excluding those in E and I) changes over time. The number of users is increasing due to social media adoption, but it is also subject to a rate of decline due to social media overload or other factors. We model this as proportional to the product of the number of social media users and the number of people engaged in the movement relative to the population size.

Equation 1b describes how the awareness of the movement changes over time, with the number of social media users becoming aware of it proportional to the number of users who are already aware of it, as well as the rate at which influencers promote it. The rate of awareness is also subject to a rate of disengagement due to social media overload, which is proportional to the product of the number of social media users and the number of people engaged in the movement.

Equation 1c describes how the size of the movement changes over time, with the number of people becoming engaged in the movement being proportional to the number of social media users who are aware of it and the available population who may join the movement, but also subject to a rate of disengagement.

Finally, Equation 1d describes how social media users the platform, with the rate simply being proportional to those not actively involved in a movement that would keep them invested.

4 Results

There are certain cases we can take into consideration and analyze depending on the parameters k_1 through k_8 . In order to simplify the analysis the parameters not relevant to the specific case are set to a default value which is equal to 0.5. If the default value is changed, the pattern of the graph is scaled inversely to the change of the k -value. The time length considered in each case varies in the number of months, such that the graphs can be easily interpreted. The initial distribution of the number of people to each category is the following: E starts at 0, S starts with 5 numbers equally spaced out in between 0.1 and 0.9 and I starts with 5 numbers equally spaced out in between 0.005 and 0.1.

Case 1: Rapid growth followed by quick decline, $k_1 \gg k_5$

Assuming that k_1 is much greater than k_5 , the social movement is likely to experience rapid growth as more and more social media users become engaged

and stay involved. However, if k_2 (rate of actively engaged people leaving the movement) is also high, the movement could fizzle out quickly as actively engaged individuals leave. If it was low, the movement could continue to grow and attract even more engaged individuals.

Simulating this with a low k_2 -value (Figure 2) we see an increasing number of people aware and actively involved in the movement stabilizing at around 0.2, with the actively involved people stabilizing at a slightly higher frequency. The number of people who are unaware of the movement stabilises at a frequency of around 30% of the population.

Using a high k_2 -value on the other hand (Figure 3), the movement dies down after only a few weeks, so the number of people who are aware of it goes to zero. The number of people who are on social media but are unfamiliar with the movement stabilizes at around 0.5, because there will always be a certain amount of people who will not be on social media and we set the rate of people leaving and joining social media as the same values. The stabilization also occurs much quicker than in Figure 2.

Interpretation

While the movement experiences rapid growth in its initial stages, the frequencies stabilize after a few weeks. The limit depends on the rate of active people leaving the movement, k_2 . If k_2 is low all three categories stabilize at a limit bigger than zero. However, if k_2 is high the movement dies out after only a few weeks. We can interpret this as telling us that even if a large number of people are drawn towards a movement, it will lose traction if it is not engaging enough to keep active members involved and interested. Therefore, it is important to strike a balance between retaining engaged individuals and allowing individuals who no longer align with the movement's goals to leave, in order to ensure the long-term success and impact of the movement.

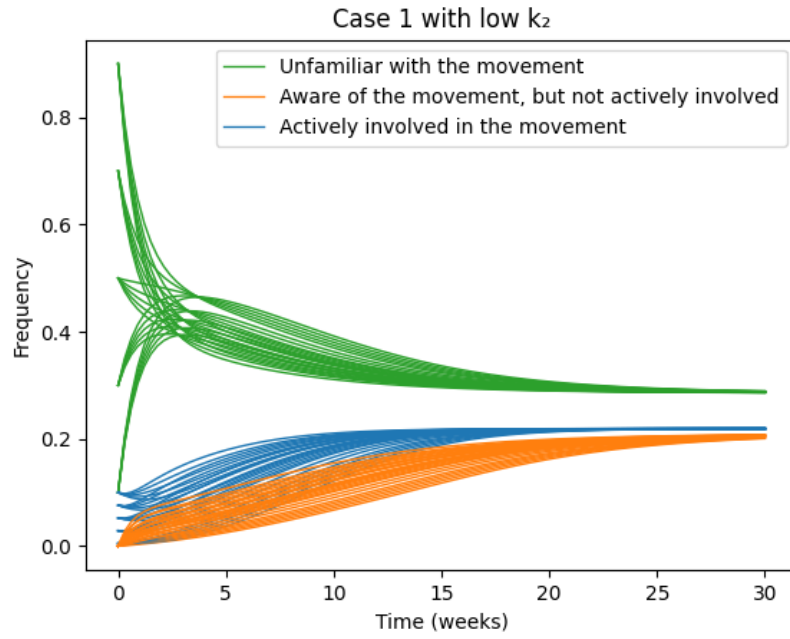


Figure 2: Many overlaid time series of the model involving $k_1 = .9$, $k_2 = .2$, $k_5 = .1$

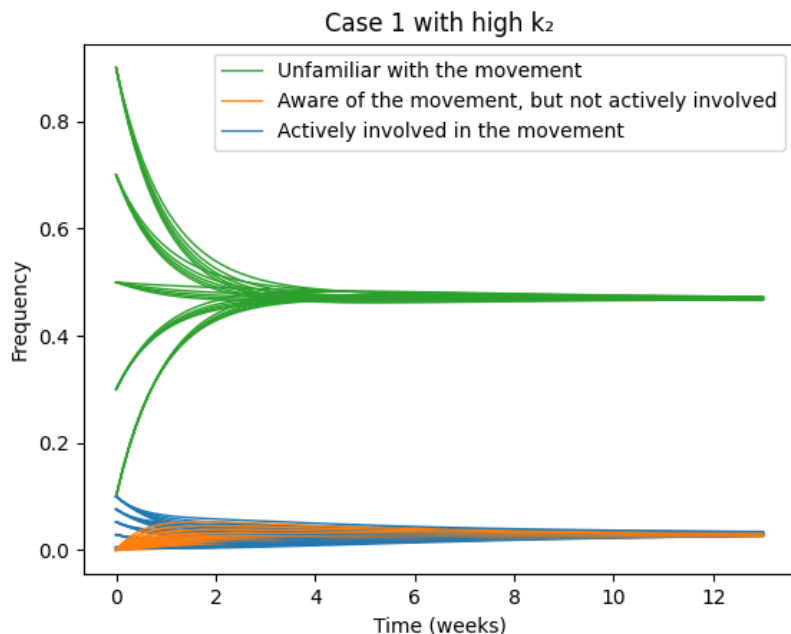


Figure 3: Many overlaid time series of the model involving $k_1 = .9$, $k_2 = .8$, $k_5 = .1$

Case 2: Struggling to gain traction, $k_3 < k_1$ and $k_3 < k_5$

Assuming that k_3 is much smaller than k_1 and k_5 , the social movement may struggle to gain traction as social media users are not becoming aware of the movement at a fast enough rate, and exposed individuals are disengaging quickly.

In Figure 4 similar to Case 1 with a high k_2 the movement dies down and the frequency of people on social media who are unfamiliar with the movement stabilizes again at around 0.5.

Interpretation

The movement struggles to gain momentum and grow and eventually it dies out. However, if the rate at which influencers promote the movement (k_4) is high, then the movement could still gain traction and attract more engaged individuals, despite a slow initial growth. After trying, we have concluded, that the k_4 value alone is not sufficient to save the moment, the values of other parameters need to be adjusted as well. This means that even if there is a small but dedicated following for a movement, it may not spread effectively if the reach of the movement is low. This may be because of reasons such as posts only being circulated within these small dedicated circles, even if many posts are being made. Therefore, it is important to consider both the rate of exposure to

the movement and the influence of key individuals in promoting and sustaining momentum for the movement.

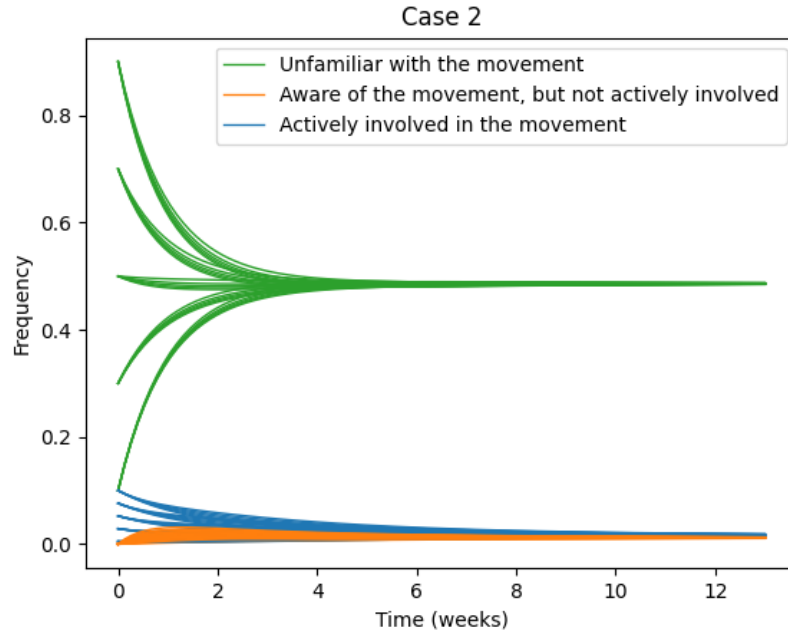


Figure 4: Many overlaid time series of the model involving $k_1 = .7$, $k_3 = .1$, $k_5 = .7$

Case 3: Influencers driving movement forward, $k_4 > k_5$

In this case, influencers could play a key role in driving the movement forward by promoting it frequently. The movement is more likely to gain momentum and have a lasting impact. This is because influencers can help sustain engagement and encourage continued participation even as individuals may be exposed to negative or disengaging factors. By promoting the movement and highlighting its benefits and impact, influencers can motivate individuals to become engaged and invested in the movement. This can help sustain participation over time and mitigate the potential negative effects of disengagement on exposed individuals.

In Figure 5 the frequency of people unfamiliar with the movement stabilize at around 0.4, whereas the frequencies of the other two groups stabilize at around 0.1. Compared to Figure 2 this time the limit of the frequency of people who are actively involved in the movement is a bit below the limit for those who are aware but not actively involved.

Interpretation

The movement continues to thrive, even if some exposed individuals disengage. This case underscores the importance of the role of influencers in promoting a social movement and sustaining engagement over time.

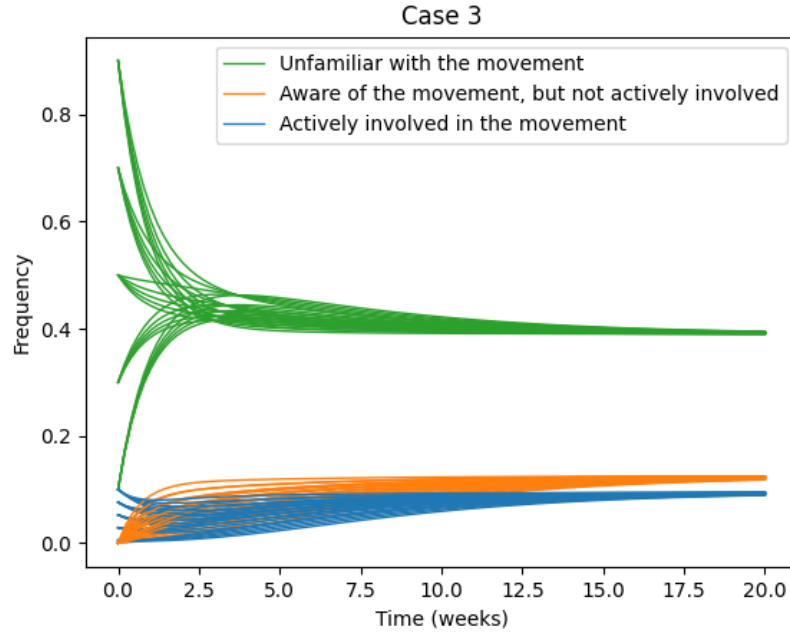


Figure 5: Many overlaid time series of the model involving $k_4 = .9$, $k_5 = .2$

Case 4: High influx of new users with potentially high risk of burnout, $k_6 > k_3$ and $k_6 > k_5$

In this case, the movement has the potential to rapidly gain momentum and reach a wide audience. As more individuals in the community join social media, they become exposed to the movement and may become engaged and invested in its goals and objectives. This can help sustain momentum and encourage continued participation, particularly if efforts are made to retain engaged individuals and address negative factors contributing to disengagement.

However, it is also important to consider the potential challenges associated with rapid growth and expansion. As the movement gains momentum and reaches a wider audience, it may become more difficult to maintain cohesion and direction, particularly if there are diverse opinions and perspectives participants.

Interpretation

In summary, this case highlights the potential benefits and challenges associated with rapid growth and expansion in a social movement. By complementing efforts to increase visibility and engagement with broader strategies to manage growth and maintain cohesion, social movements can maximize their impact and reach a wider audience. This case only concerns itself conceptually with the number of people. Therefore there is no graph to represent it as it will stabilize itself at similar ratios as the other graphs.

Case 5: Not enough new social media users, $k_3 > k_6$

In this case, the movement may struggle to gain traction and expand its reach beyond initial participants.

While efforts to raise awareness of the movement existing social media users may help to generate initial interest and support, the movement may struggle to expand its reach beyond this initial group without effective strategies for engaging individuals who are not already using social media.

In such a scenario, it may be useful to consider strategies for increasing social media adoption non-users, such as targeted advertising or outreach efforts. Additionally, efforts to establish partnerships with organizations and groups outside of social media can help to generate broader support and reach individuals who may not be engaged through social media alone.

As can be seen in Figure 6 the awareness of the movement increases initially but slowly dies down, as predicted. What is interesting in this case, is that even though k_3 is much higher than k_6 not all of the social media users will be familiar with the movement. This might be due to the parameters k_2 and k_5 of people leaving the movement, whether they were active or not. Since both of these parameters are relatively high (default value of 0.5) they have a large influence on the group sizes.

Interpretation

Depending on multiple parameters, the movement is likely to plateau and fails to reach new individuals. Since our model allows for people to lose and regain interest in the movement, it will stabilize after some weeks.

This case highlights the potential challenges associated with relying solely on social media to promote and sustain a social movement. By complementing efforts to increase awareness and engagement on social media with strategies for engaging non-users and establishing partnerships with organizations outside of social media, social movements can maximize their impact and expand their reach beyond initial participants.

This case is not generally very common as there are often many social media users in increasing numbers, but it may be more applicable in smaller rural communities where there is low usage of social media or low interest in / access to technology.

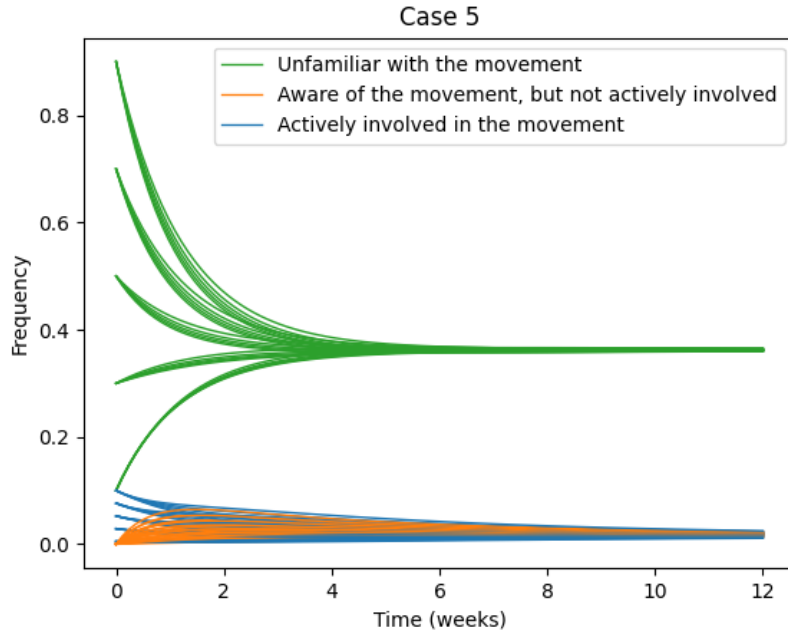


Figure 6: Many overlaid time series of the model involving $k_3 = .8$, $k_6 = .3$

Case 6: High influencer promotion giving diminishing returns, $k_4 > k_5$ and $k_8 > k_7$

In this case, influencers are effectively promoting the movement ($k_4 > k_5$) and social media users are leaving the platform at a slower rate than they are joining it ($k_8 > k_7$). This means that while social media may be overwhelming some users, it's still an effective tool for spreading awareness and engaging new supporters.

As can be seen in Figure 7 the three groups stabilize after a few weeks at non-zero values. This shows that the social movement will be continued on at that level for some time until one of the parameters changes.

Interpretation

The movement is likely to continue growing in popularity, but social media may need to find ways to reduce user overload and keep existing users engaged. In real life, the parameters are probably going to change after some time, which means that the system will never stabilize.

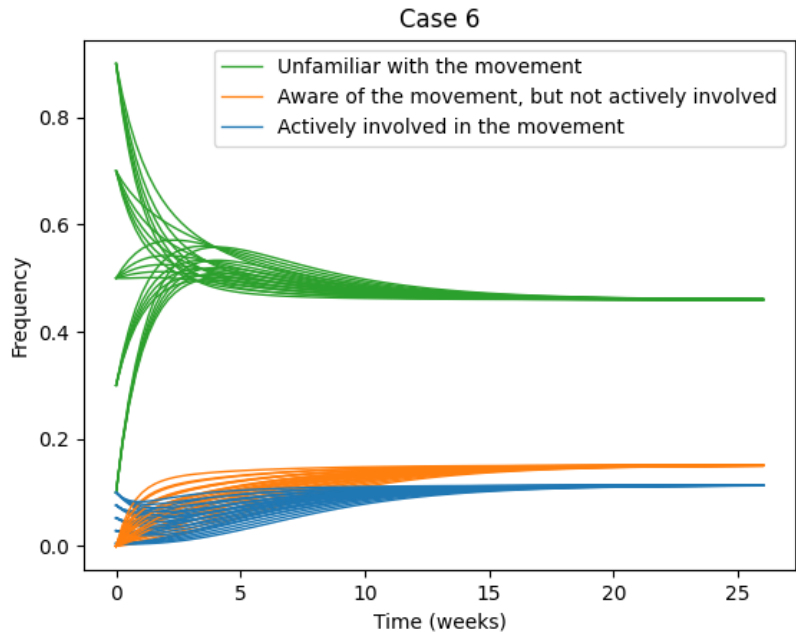


Figure 7: Many overlaid time series of the model involving $k_4 = .7$, $k_5 = .3$, $k_7 = .3$, $k_8 = .7$

5 Discussion

Social movements are much more dynamic than shown in our model. They can grow or die down within hours to years, depending on how the circumstances change, how the movement and its goals is interacted with as a society and not only on social media [6]. Our model simplifies this complex movement and puts it into a world without any exterior influences that could change the parameters. This means, that the most “realistic” part of the time series might only be the first week or so since the real world never gives a specific movement enough time to stabilize itself.

In reality, movements tend to die down or plateau for a variety of reasons which may be hard to quantify, which ties into the scope and assumptions of this project, such as the cause of the movement being resolved. In practice, even the parameters we discussed should be considered differently depending on the goals of the movement. For example, a movement desiring long-term societal change should concern itself more with being long-lasting and widespread as opposed to a movement which wishes to immediately address a pertinent issue, which should seek to grow rapidly to gain attention from specific parties.

After working with and interpreting a few cases for our model, we observe

that our functions all seem to stabilize, but just with varying speeds and limits. This is to be expected as our main goal was to analyze how quickly social movements grow with varying social media exposure, influencing power, and active social media use rather than working with stability cases like what we've seen in our lectures.

From the case analysis graphs, we can see that social media does in fact play a role in boosting the growth of social movements, but only when accompanied by other factors. For instance, if we have a large number of influencers/infected individuals but their rate of infecting is very low for various reasons such as bad quality posts or not reaching the proper demographic, then their efforts won't be as effective. Thus, if politicians or those in a social movement decide to use their resources on social media, they have to ensure that it's effective and properly correlates to the demographics that they're trying to persuade.

Cases 1 and 2 highlight the importance of the so-called "attention economy" of modern social media. Modern movements must be exciting, engaging, and attention-grabbing in order to find and keep the attention of users. With the rise of short-form content and the average user's attention span dropping[9], tactics to prevent loss of interest must be employed by a movement if it wishes to reap the full benefits of social media use. At this point, a movement should start considering methods of promotion that can be more engaging with better reach. For example, considering varying their types of posts to include posts that spread more awareness easily such as emotionally impactful stories and photos, infographics, short-form video, and more.

Social media movements can be seen as similar to brands in that they must employ effective "advertising" tactics to see growth and retention. However, they feed off of emotional impact, empathy, and a desire to see improvement in the world. Thus, it becomes important to understand how the factors we have examined can influence a movement in order to enact meaningful change in the modern era.

To try and answer our previously mentioned research questions, we conclude that k_4 does play a significant noticeable role in promoting/inhibiting movement growth. This makes sense in a social setting as having a high rate of influencers being able to promote the movement directly affects the rate at which users join the movement. k_2 also seemed to affect the limit at which our graphs stabilized like with case 1 which again correlates to the importance of keeping people in the movement engaged in it. Thus, having both effective social media campaigns and continuing involvement in the movement is necessary for a social movement to spread. We can summarise to say that social media helps boost initial traction of movements and reduces disengagement by employing persuading social media propaganda.

A few ways to increase the accuracy of our results would be varying the constant parameters k_1 to k_8 in each of the cases. For accuracy purposes, we should conduct all the cases with varying case parameters as well, for instance, having $k_1 = k_5 = 0.99$ and $k_3 = 0.01$ in case 2, etc. However, after analyzing these different cases, there didn't seem to be any significant differences from what we already found. Another suggestion would be to conduct the study

with a base value of 0.2 or 0.7 instead of just 0.5. This would help us analyze how fast social movements grow and stabilize with varying exposure to social media. A more accurate model would be to add another variable or change the parameters to variables, as it would be easier to model the changes within the movement and the world that surrounds it.

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6 Appendix

Source code for this document and all its figures is available at <https://github.com/cicilapetitesorciere/Social-Movements-Report>