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Rumor Simulation with Emotional Agents

by

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Contents

List of Figures

List of Tables

List of Abbreviations

I Infectious

R Recovered

S Susceptible

List of Symbols

$Base_\alpha$ A base probability of infection

wa_α A weight of arousal in Infection Probability

wv_α A weight of valence in Infection Probability

$Base_\beta$ A base probability of recovery

wa_β A weight of arousal in Recovery Probability

wv_β A weight of valence in Recovery Probability

$\sigma(x)$ Sigmoid function

Acknowledgment

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Abstract

Emotion is one of the significant factors in rumor propagation. In this research, we examine how emotional states affect rumor propagation by implementing two SIR-based simulations in The Sims 4: one with emotional agents and one without emotional agents.

A custom mod was developed to record each Sim's state, emotions, traits, relationships, and interactions. We also represent emotions as arousal and valence, and define formulas for infection and recovery probabilities. Infection occurs during conversation. Recovery occurs after set in-game time intervals.

The simulation results suggest that incorporating emotional states significantly alters rumor propagation dynamics. Especially, Susceptible Sims rapidly decreased, and Infectious Sims rapidly increased at Willow Creek and Oasis Springs. However, there are no significant differences between the simulation with and without emotion at Newcrest, likely due to lower population density and reduced diversity of Sims' emotions.

This research highlights the critical role of emotional arousal in accelerating rumor spread emphasize the importance of integrating emotional factors into simulation models of rumor propagation.

Chapter 1

Introduction

In recent years, rumors spread widely across online and offline communities. Some of these rumors can be harmful, and they are often without scientific evidence. For instance, in early 2020, numerous misinformation and unfounded claims about COVID-19 rapidly spread, such as unverified foods or practices believed to prevent infection, leading to confusion and social disruption. Because of such cases, understanding the mechanisms behind rumor propagation has become an important research topic.

However, the dynamics of rumor spreading in complex societies are difficult to model, as rumors interact with people's emotions, social ties, and situational contexts. To address this challenge, many studies have adopted agent-based simulations. For example, Tianrui Hu et al. introduced a framework that utilizes LLM-driven agents to investigate the spread of rumors and misinformation within social networks [1]. Yijun Liu et al. proposed a dynamic and hierarchical social network simulation framework, along with a multi-agent interaction strategy inspired by information cocoon theory, to enhance the realism and efficiency of rumor-propagation simulation [2].

Despite these developments, most previous works do not explicitly incorporate detailed emotional states of agents, even though emotions strongly influence human communication and information acceptance. It is often mentioned that emotion is one of key factors in rumor propagation. For instance, Nicolas Pröllochs et al. empirically analyzed to what extent emotions explain the diffusion of online rumors [3]. Contrary to traditional findings in offline settings where negative emotions dominate, they observed that online rumor diffusion is more pronounced for positive emotions and the largest estimated effect size is associated with Aggressiveness [3]. Even in studies that introduce emotions, emotional modeling often remains simplified. For example, Qian Li et al. presented a message propagation model based on rumor, anti-rumor, and stimulate-rumor [4]. Also, agents may enter a hyperactive state to represent complex psychological reactions during rumor propagation [4]. Nevertheless, such models do not differentiate between specific emotions such as anger, sadness, or happiness, which are known to affect how individuals interpret, convey, or ignore information. Therefore, existing models may not sufficiently capture the effects of emotional states on rumor propagation.

1.1   Research Objectives

This study examines the impact of emotional factors on rumor propagation dynamics. Specifically, it investigates whether incorporating emotional states accelerates or

suppresses the rate of rumor spreading.

To achieve this, we use The Sims 4, a large-scale social simulation game where agents naturally exhibit diverse emotions, personality traits, and social relationships. This environment enables observation of location-dependent interactions and encounters that influence rumor transmission.

Rumor propagation is modeled using an SIR-based framework. Epidemic models have long been applied to rumor diffusion because both processes involve transitions among susceptible, infectious, and recovered individuals through interpersonal contact [5]. However, the mechanisms governing the removal of infectious individuals differ. In epidemics, infectious individuals die or are isolated to join the removed class at a rate proportional to their own numbers [5]. Moreover, with rumors, there are other ways whereby infectious individuals cease to act as spreaders: they can become discouraged as an outcome of encounters either with one another or with recovered individuals [5].

By integrating an SIR-based rumor propagation model into The Sims 4 through a mod, we aim to examine how emotional factors alter the dynamics of rumor spreading in a socially complex environment.

1.2 Significance of Research

The significance of this research lies in providing a simple framework for simulation of rumor propagation and emotional factors. This framework has the potential to help understand emotional effect, rumor propagation and human behavior.

Chapter 2

Background

This section explains the details of the SIR model, The Sims 4, and a Circumplex Model of Affect. The SIR model is the basis of our simulation. The Sims 4 is utilized to calculate the effect of emotions.

2.1 SIR Model

The SIR model is a mathematical model used to simulate how population moves between different states. It divides individuals into three classes:

- Susceptible (S): individuals who have not yet heard the rumor.

- Infectious (I): individuals who actively spread the rumor.

- Recovered (R): individuals who are no longer interested in spreading it.

In the classical SIR model, transitions between the three states are described by the following differential equations:

$$\frac{dS}{dt} = -\beta SI$$
$$\frac{dI}{dt} = \beta SI - \gamma I$$
$$\frac{dR}{dt} = \gamma I$$

where β represents the transmission rate and γ represents the recovery rate.

Although W. O. Kermack et al. proposed this model for epidemics where they considered a fixed population [6], it also has been widely adapted to describe the spread of rumors because both processes involve transmission through interpersonal contact and transitions among susceptible, infectious, and recovered individuals [5].

However, rumor propagation differs from disease spread in removal process of infectious individuals. Individuals may stop spreading a rumor not only through isolation or recovery, but also through an outcome of encounters either with one another or with recovered individuals [5]. Therefore, rumor models often reinterpret the recovered state as individuals who no longer participate in spreading [5].

Rumor propagation models based on SIR model assume probabilistic transitions driven by contact between infected and susceptible individuals. This framework can capture the fundamental diffusion dynamics so many studies use it as the base of the model. For example, Xinyang Wang et al. introduced new entities such as Positive information disseminators, Negative information disseminators, and announcers into the SIR model to simulate the evolution path of real online public opinion events [7]. However, traditional SIR models do not incorporate emotional or psychological factors deeply. They treat them only in a simplified manner.

In this study, we adopt an SIR-based framework and extend it by incorporating emotional states into the transition probabilities. This extension enables the investigation of how psychological factors influence rumor propagation dynamics in a socially complex environment.

2.2 The Sims 4

The Sims 4 is a large-scale social simulation game developed by Maxis and published by Electronic Arts. Each Sim possesses a wide range of properties, including personality traits, emotional states (mood), interpersonal relationships, and autonomous behaviors. Importantly, Sims experience diverse emotions such as anger, sadness, happiness, or stress based on their environment, interactions, and personal attributes.

This environment provides an environment that reflects real-world social environments. Traditional SIR-based models typically assume homogeneous mixing, meaning that each individual has an equal probability of interacting with any other individual in the population. It does not reflect real social behavior, where interactions are influenced by spatial proximity, daily routines, and social relationships. In the real world, rumor transmission depends on when and where individuals encounter others and how frequently they interact. Encounters occur among nearby individuals and are shaped by movement patterns, shared spaces, and interpersonal relationships.

To capture these dynamics, this study uses The Sims 4 as a social simulation environment. By utilizing a modding framework, the game allows extra scripts to track Sims' states, detect social interactions, and implement custom models such as rumor dynamics based on the SIR model. This makes The Sims 4 suitable for exploring how emotional factors influence information spreading in a complex and realistic virtual society. To make a mod, we used the template of Sims4CommunityLibrary provided by ColonolNutty [8].

2.3 A Circumplex Model of Affect

A Circumplex Model of Affect [9] is a framework that can represent emotion in two dimensions. The X-axis can represent valence, and the Y-axis can represent arousal. Valence shows how pleasure this emotion is. For example, happiness gets a plus value, but sadness gets a minus value. On the other hand, arousal shows how this emotion activates us. For instance, tense becomes high, although relaxation becomes low.

In our study, we used this to introduce emotion into the SIR model because this can easily represent emotional continuity. We decided that valence will take from -1 to 1, and arousal will take from 0 to 1. For instance, we defined that anger is -0.8 as valence

and 0.9 as arousal. Furthermore, we defined other emotions. The details is shown in Table 3.1.

Chapter 3

Method

In this section, the details of the mod are explained. We developed the mod using Python and Sim4CommunityLibrary. To introduce emotion into the simulation, the emotions of Sims are mapped to valence and arousal. These are included in the formulas of infection probability and recovery probability. Furthermore, we tried to include personality traits and interpersonal relationship levels. These are also important in the rumor propagation.

3.1   Mod Development

We developed a custom mod for The Sims 4 using Python and Sims4CommunityLibrary [8]. The mod retrieves real-time information about each Sim, including the following:

- Current emotion (mood)

- Valence and arousal derived from emotion

- Personality traits related to emotional expressiveness

- Interpersonal relationship levels between Sims

- Conversation events that represent social contact

3.2   Emotion Modeling

Each Sim's mood is mapped to two emotional dimensions:

- Valence (-1 to 1): representing pleasantness

- Arousal (0 to 1): representing activation level

These values are defined based on the Circumplex Model of Affect, and the in-game description of Sims' emotions. Mapping emotions onto valence and arousal enables the quantitative integration of affective states into the rumor propagation model.

For example, emotions such as anger and embarrassment were assigned negative valence, while happiness was assigned positive valence. Highly activating emotions (e.g., anger, energized) were assigned higher arousal values, whereas sleep or sad states were assigned lower arousal levels. The values are shown in Table 3.1.

Table 3.1: Assigned valence and arousal values

Emotion	Valence	Arousal
Angry	-0.8	0.9
Bored	-0.4	0.1
Confident	0.7	0.8
Dazed	-0.6	0.1
Embarrassed	-0.6	0.8
Energized	0.6	0.9
Fine	0.0	0.5
Flirty	0.6	0.9
Focus	0.3	0.6
Happy	0.9	0.8
Inspired	0.7	0.7
Playful	0.8	0.8
Possessed	-0.5	0.7
Sad	-0.9	0.2
Sleeping	0.1	0.0
Stressed	-0.7	0.8
Uncomfortable	-0.6	0.7

3.3 Personality traits

Sims have personality traits such as Cheerful, Gloomy, or Hot-Headed. The emotional traits are assigned small modifiers representing emotional effect. The values are shown in Table 3.2.

Table 3.2: Assigned values to each emotional trait

Emotional Traits	Value
Ambitious	0.0
Cheerful	0.1
Childish	0.0
Clumsy	-0.1
Creative	0.0
Erratic	0.1
Genius	0.0
Gloomy	0.1
Goofball	0.1
Hot-Head	0.1
Practice Makes Perfect	0.0
Romantic	0.1
Self-Assured	0.0

Positive values indicate increased influence on rumor propagation, and negative values indicate decreased influence on rumor propagation, regardless of whether the emotion is positive or negative.

3.4 Interpersonal relationship levels

Sims have interpersonal relationship levels with other Sims, which are friendship level and romance level. Both friendship level and romance level take from -100 to 100. We use the average of these two values as a relationship metric.

3.5 SIR Dynamics with Emotion

Each Sim holds current states Susceptible (S), Infectious (I), or Recovery (R). Transitions occur only during conversation events between Sims, or at fixed time intervals. Sims holding a current state S can become only a state I. Sims holding a current state I can become only a state R. Sims holding a current state R cannot become other states.

3.6 Infection Probability

This represents the probability of transitioning from a current state S to new state I. This probability is evaluated when a conversation event occurs between two Sims, where one of them is Susceptible and the other is Infectious.

In this study, the infection probability is defined as the following:

$$P_{Infection} = \sigma(logit(Base_\alpha) + Emotion)$$

where

$$Emotion = -wv_\alpha * valence + wa_\alpha * arousal + emotional\_traits + \frac{relation}{100}$$

$Base_\alpha$ is the base probability of infection. $\sigma(x)$ makes the range from 0 to 1. Then, logit creates a standard in the $\sigma(x)$ function. wv_α, and wa_α are the weight of valence, and arousal. $\frac{relation}{100}$ represents normalizing the interpersonal relationship level to the range of [-1, 1]. The diffusion of offline rumors is pronounced for negative emotions. Therefore, in this experiment, while positive emotions decrease infection probability, negative emotions promote infection. Furthermore, the more arousal, the higher the infection probability because it is difficult to make calm judgments when a person is excited.

In the simulation without emotion, the infection probability is a special case when $Emotion = 0$. It can be written as the following:

$$P_{Infection\_without\_emotion} = \sigma(logit(Base_\alpha))$$

In the simulation with emotion, the infection probability can be written as the following:

$$P_{Infection\_with\_emotion}$$
$$= \sigma(logit(Base_\alpha) - wv_\alpha * valence + wa_\alpha * arousal$$
$$+ emotional\_traits + \frac{relation}{100})$$

3.7 Recovery Probability

This represents the probability of transitioning from a current state I to new state R. This probability is evaluated at fixed time intervals in case that the Sim is Infectious.

In this study, the recovery probability is defined as the following:

$$P_{Recovery} = \sigma(logit(Base_\beta) + Emotion)$$

where

$$Emotion = wv_\beta * valence + wa_\beta * (1 - arousal) + emotional\_traits$$

$Base_\beta$ is the base probability of recovery. As same as in the infection probability, $\sigma(x)$ makes the range from 0 to 1. Then, logit creates a standard in the $\sigma(x)$ function. wv_β, and wa_β are the weight of valence, and arousal. We defined emotional effects in recovery as the opposite of those in infection. Therefore, in this experiment, positive emotions help people get away from rumor. Additionally, the lower the arousal, the higher the recovery probability because it is easy to stabilize their cognitive function when a person is calm.

In the simulation without emotion, the recovery probability is a special case when $Emotion = 0$. It can be written as the following:

$$P_{Recovery\_without\_emotion} = \sigma(logit(Base_\beta))$$

In the simulation with emotion, the recovery probability can be written as the following:

$$P_{Recovery\_with\_emotion}$$
$$= \sigma(logit(Base_\beta) + wv_\beta * valence + wa_\beta * (1 - arousal)$$
$$+ emotional\_traits)$$

3.8 Observe Sims

In the game, the engine frequently respawns and despawns Sims. However, each Sim retains the same unique ID. When a Sim is respawned, it is added to the model as Susceptible if it has not been recorded previously. When a Sim is despawned, recovery events are not adapted until the Sim is respawned.

Chapter 4

Evaluation Method

This section describes the experimental setup and procedure. Experiments are conducted in three locations. We play the game at each location to make the Sims' emotions diverse. After that, the mod is activated, and the simulation is working for six hours.

4.1 Initial Conditions

Experiments are conducted in three representative locations within the game: Willow Creek, Oasis Springs, and Newcrest. Additionally, at the start of the game, almost all Sims initially have neutral emotional states. This is not suitable for experiments. Therefore, we play at each location for approximately one hour, which begins with making the players' Sim. This allows emotional diversity to emerge among Sims. Furthermore, in this experiment, the values of the weights of valence and arousal, and the base probabilities are shown in Table 4.1.

Table 4.1: The values of variables

| $Base_\alpha$	wv_α	wa_α	$Base_\beta$	wv_β	wa_β
0.1	1.2	1.4	0.01	1.1	1.3

$Base_\beta$ value is much lower than $Base_\alpha$ to prevent quickly recovering from infectious. Rapid recovery is not suitable for observing differences between simulations with and without emotion.

4.2 Simulation Procedure

The simulation procedure is shown in Fig 4.1.

Furthermore, the game's speed is automatically controlled by the game itself. Usually, the game's speed is normal speed. However, in some cases, such as sleeping or working, the game's speed is ultra speed.

10

Figure 4.1: Simulation Procedure
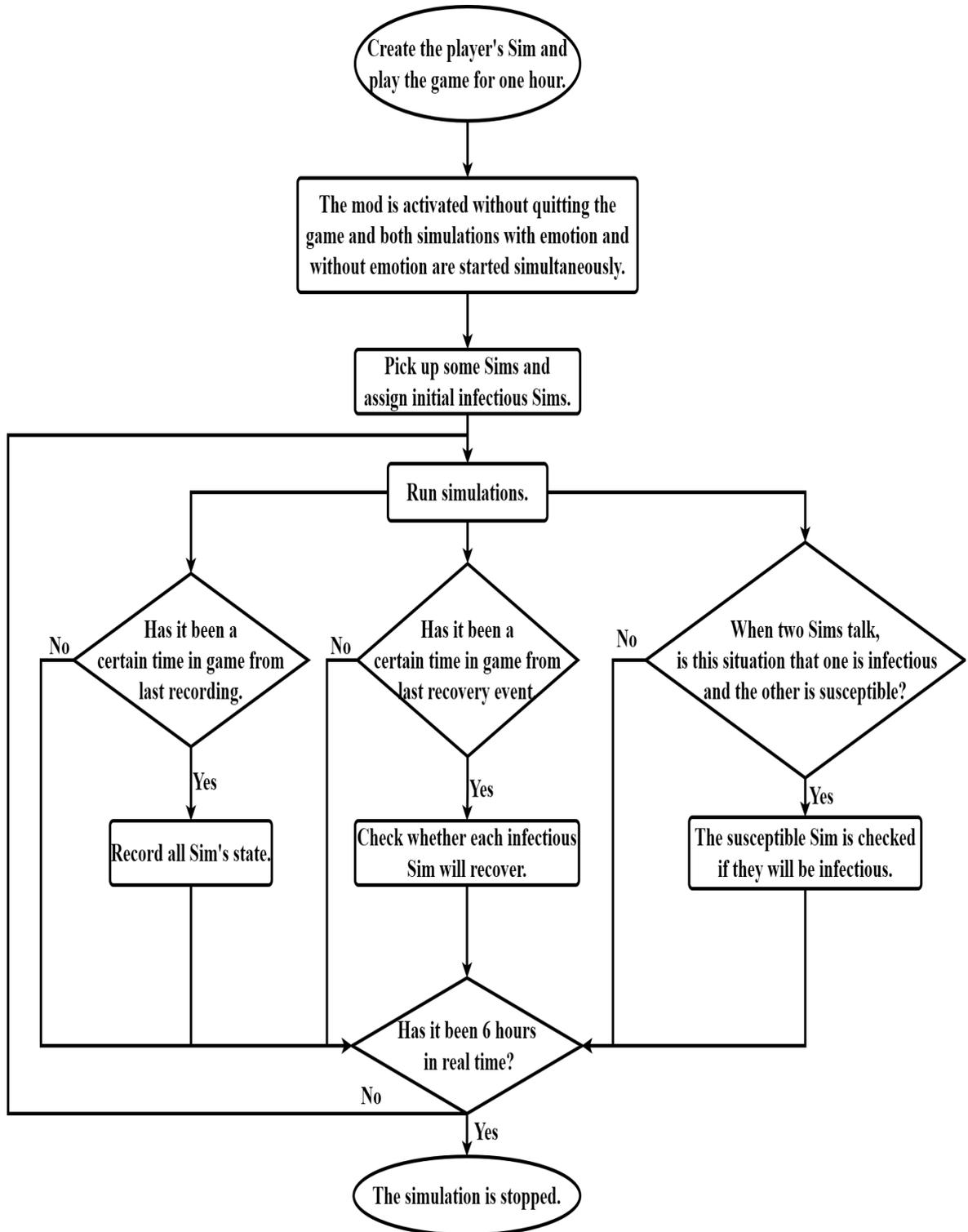
Chapter 5

Result

This chapter presents the experimental results of the proposed simulations.

5.1 Differences Between Simulations With and Without Emotion

Table 5.1 summarizes the number of conversations and the initial and final populations of Susceptible, Infectious, and Recovered Sims at each location.

Table 5.1: The amount of conversation and the population for each location.

Location	Willow Creek	Oasis Springs	Newcrest
The amount of conversation	374	539	281
Initial population	S: 53, I: 3, R: 0	S: 58, I: 3, R: 0	S: 48, I: 3, R: 0
Final population of simulation with emotion	S: 27, I: 24, R: 7	S: 37, I: 22, R: 5	S: 53, I: 3, R: 1
Final population of simulation without emotion	S: 53, I: 4, R: 1	S: 57, I: 3, R: 4	S: 51, I: 4, R: 2

At Willow Creek and Oasis Springs, significant differences are observed between the simulations with emotion and without emotion, especially in the number of Susceptible and Infectious Sims. In contrast, there are no remarkable differences at Newcrest.

5.2 Temporal Changes in Population at Each Location

Fig 5.1 shows the flows of the differences in the number of Susceptible, Infectious, and Recovered Sims between the simulation with and without emotion at Willow Creek. Fig 5.2 shows the flows at Oasis Springs. Fig 5.3 shows the flows at Newcrest.
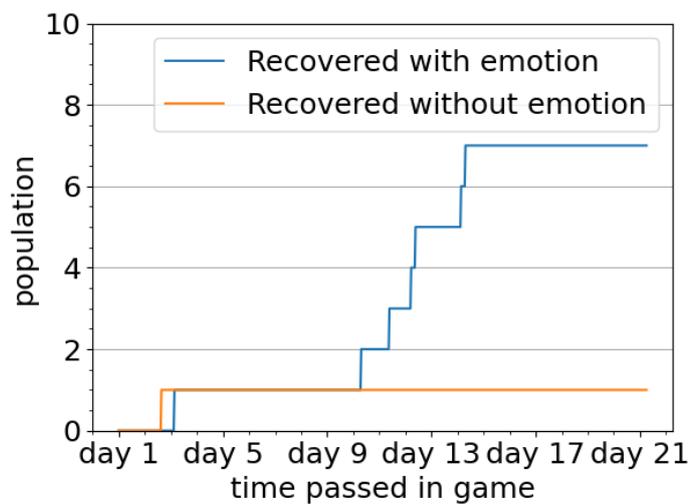
At Willow Creek, in the simulation without emotion, the changes in the population are minimal. On the other hand, in the simulation with emotion, significant changes are observed. At times, Susceptible Sims rapidly decreased, and Infectious Sims rapidly increased.
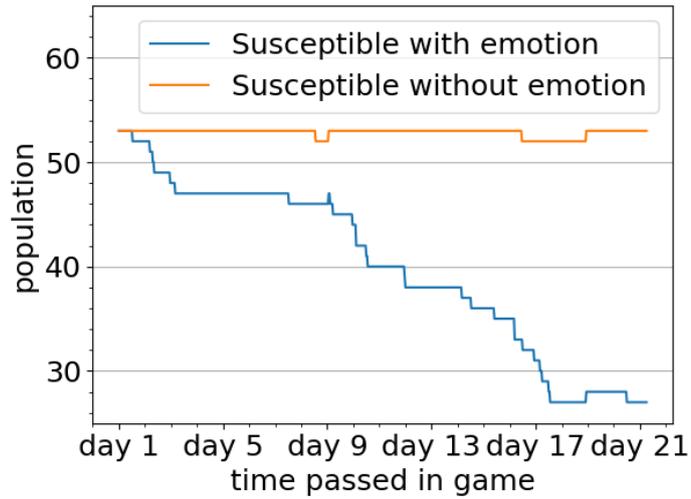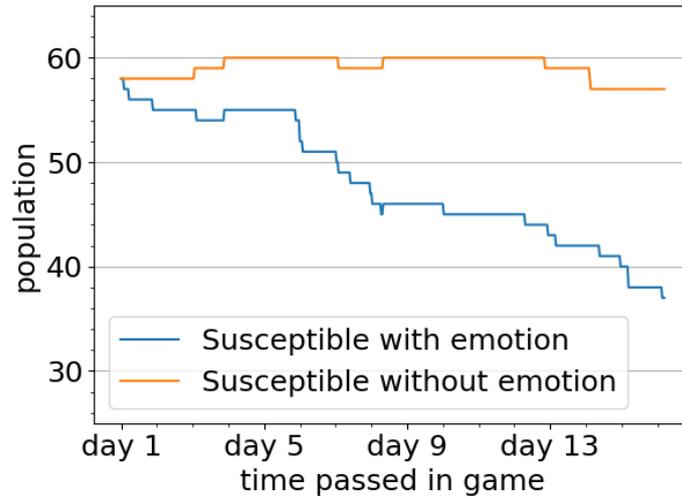
(a) Susceptible Sims at Willow Creek
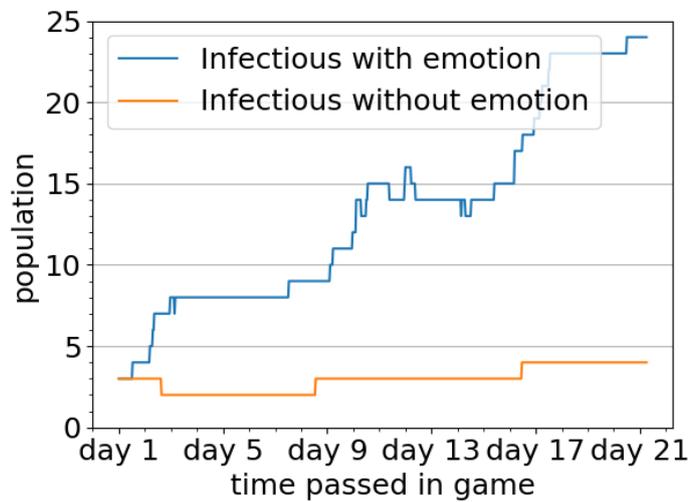
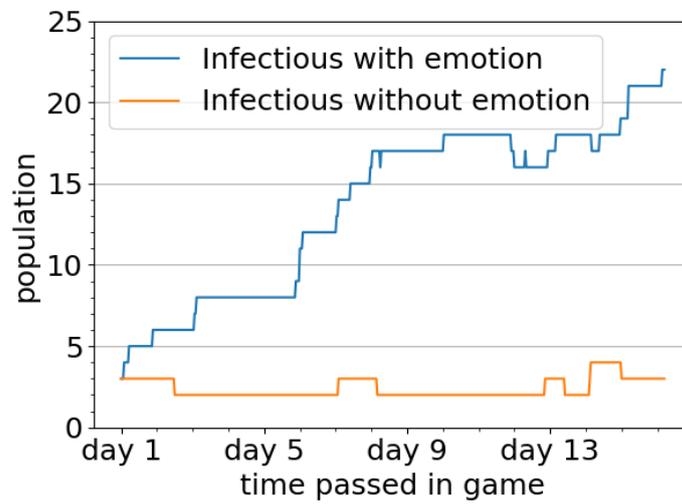(b) Infectious Sims at Willow Creek

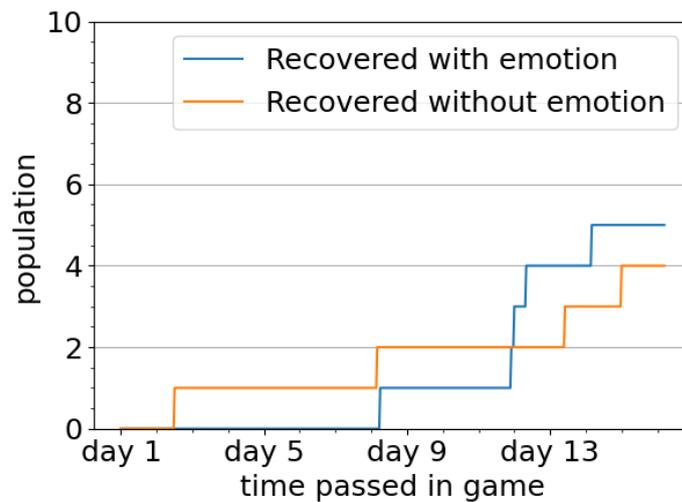(c) Recovered Sims at Willow Creek

Figure 5.1: Temporal transition of SIR model at Willow Creek

(a) Susceptible Sims at Oasis Springs

(b) Infectious Sims at Oasis Springs

(c) Recovered Sims at Oasis Springs

Figure 5.2: Temporal transition of SIR model at Oasis Springs

At Oasis Springs, the differences between simulations with and without emotion are the same as those at Willow Creek. In the simulation without emotion, the changes in the population are small. On the other hand, in the simulation with emotion, there are remarkable changes. At times, Susceptible Sims rapidly decreased, and Infectious Sims rapidly increased.

At Newcrest, the flows of the simulation with emotion are almost the same as the flows of the simulation without emotion. These changes in the population are small.

## 5.3 Diversity of Initial Sims' Emotions

Table 5.2 shows the initial Sims' Emotions. The number of fine Sims is the most in all locations. Additionally, the numbers of happy Sims are significantly different.
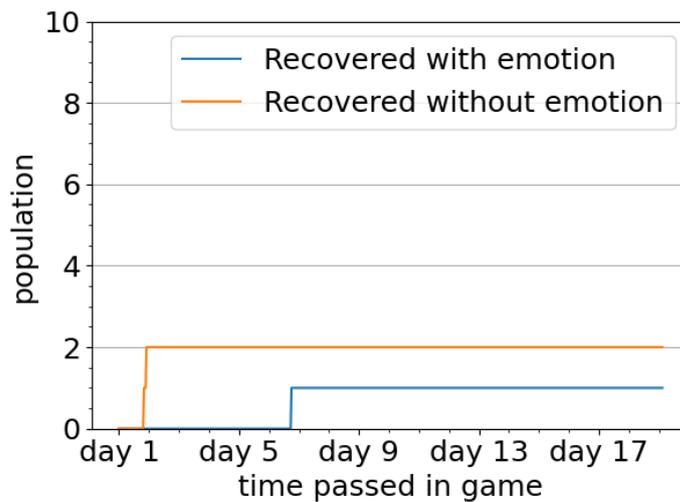
Table 5.2: Emotion Diversities

	Willow Creek	Oasis Springs	Newcrest
Angry	0	2	2
Bored	4	1	1
Confident	0	0	3
Dazed	0	0	0
Embarrassed	1	1	2
Energized	4	2	3
Fine	16	21	23
Flirty	7	9	8
Focus	1	4	3
Happy	13	9	2
Inspired	3	1	1
Playful	1	3	1
Possessed	0	0	0
Sad	5	3	2
Sleeping	0	0	0
Stressed	1	2	0
Uncomfortable	0	3	0
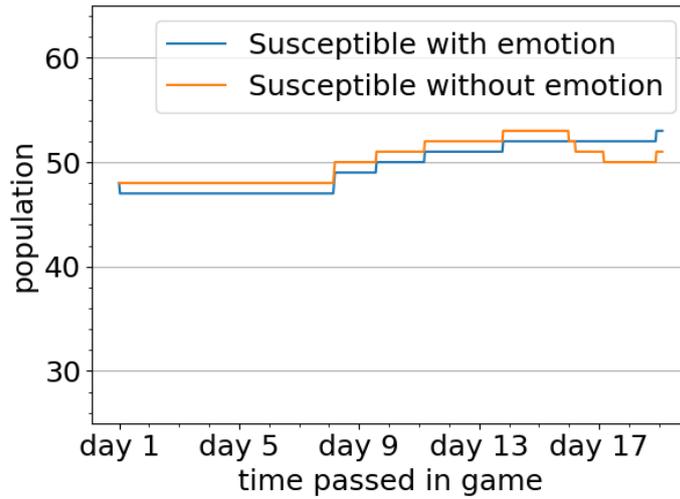
(a) Susceptible Sims at Newcrest
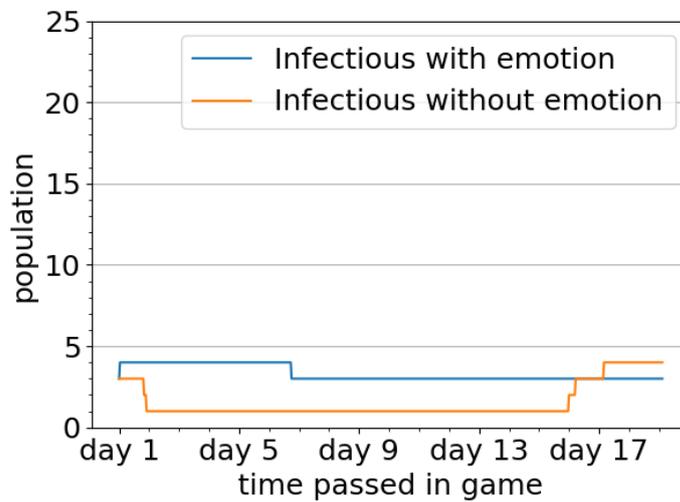
(b) Infectious Sims at Newcrest

(c) Recovered Sims at Newcrest

Figure 5.3: Temporal transitions of SIR model at Newcrest

Chapter 6

Discussion

6.1 Emotional Effects on Rumor Propagation

The results suggest that incorporating emotional states significantly alters rumor propagation dynamics. At Willow Creek and Oasis Springs, rumors spread more rapidly when emotional effects are incorporated. On the other hand, the rumor without emotional effects is spreading slowly. This can be attributed to the effect of arousal. When Sims talk to someone, their emotion usually has a high point of arousal regardless of whether the emotion is positive or negative.

However, there are no remarkable differences at Newcrest. There are three possible reasons. First, the simulation begins after one hour passed from creating a new player's Sim. Then, Newcrest has only the player's Sim's house in one area. Therefore, the density of the population at Newcrest is lower than that of others. Second, the number of conversations at Newcrest is the lowest among them. It suggests that there is a threshold between 281 and 374 to spread rumors rapidly. Finally, the number of initial happy Sims at Newcrest is the lowest, but happiness does not strongly promote the rumor propagation. Thus, the transition from happiness may become significant for spreading rumors.

Chapter 7

Conclusion

This study demonstrated that incorporating emotional states significantly alters rumor propagation dynamics. The results indicate that arousal plays a key role in accelerating rumor spread. These findings highlight the importance of integrating emotional factors into simulation models.

7.1   Limitation

There are two limitations in this study.

First, the simulation did not explicitly record the temporal transitions of each Sim's emotional states. Although emotional diversity emerged after playing the game for one hour, many Sims tended to be in a fine state initially. If this tendency persists, the influence of emotion can be suppressed in certain scenarios.

Second, the emotional impact on rumor propagation may differ depending on the type of rumor. Some rumors may be influenced by specific emotional states, while others may not be strongly affected by the emotion. Therefore, the proposed model may not generalize to all kinds of rumor propagation.

7.2   Future Work

Future work will explore various parameter settings, such as adjusting the values of arousal and valence for different types of rumors or modifying the base values for infection and recovery rates. In addition, comparisons with real-world data, such as social media, will be conducted to evaluate the realism of simulations with and without emotional effects.

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