Modeling the Evolution & Diffusion of a Rumor in a Close-Knit Community

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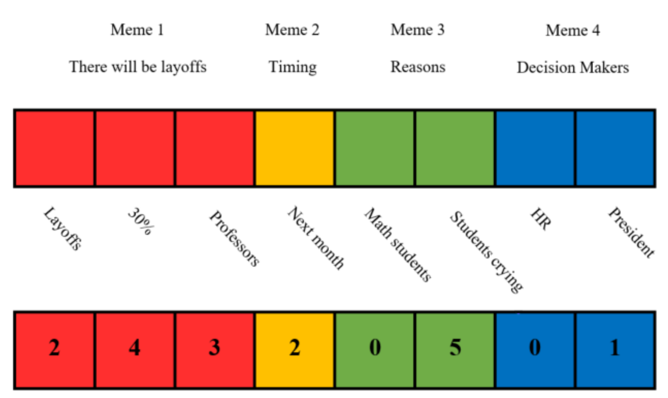
Abstract

In the age of "fake news", society has become increasingly concerned with the integrity of widespread information. Nonetheless, news spreads at alarmingly fast rates due to the power of television and social media. In an effort to capture this phenomena, we created an agent-based model that simulates the evolution of a rumor throughout a close-knit community. The simulation tracks which pieces of the rumor become distorted, restored, and lost. The goal is to understand the dynamics that affect rumor transmission, evolution, and overall fidelity.

Background Information

- An agent-based model (ABM) is a type of computational modeling that uses mathematical algorithms to simulate interactions amongst individuals in order to understand how these interactions affect the system as a whole
- We define **rumors** as unverified and instrumentally relevant information statements in circulation that that arise in contexts of ambiguity and that function primarily to help people make sense and manage threat
- We define **memes** as individual components of the rumor that provide context to the rumors integrity
- We define **codons** as the most specific pieces of data which represent the actual content of the rumor
- An example of the rumor would be: "30% of the professors in the math department are going to be laid off next month due to a math students crying. The decision was made by HR and the new president."



Key Model Assumptions

- Students always ask if the other person has heard the rumor before socializing
- Students communicate via the internet; thus, there is no need to model their locality
- Stronger relationship values correlate to higher tendencies of socializing
- Students are less likely to believe a rumor with higher distortion
- Students know the truthfulness value of their peers

Agents, Rumor, and Links

- Agents represent the students of Rhodes College
- Agents belong to one of four social groups: sports, clubs, greek, housing
- Agents can belong to multiple social groups but only one sub-group in each
- The rumor is an array made up of codons ranging [0, 5]
- Each undirected link represents a common sub-group between two agents

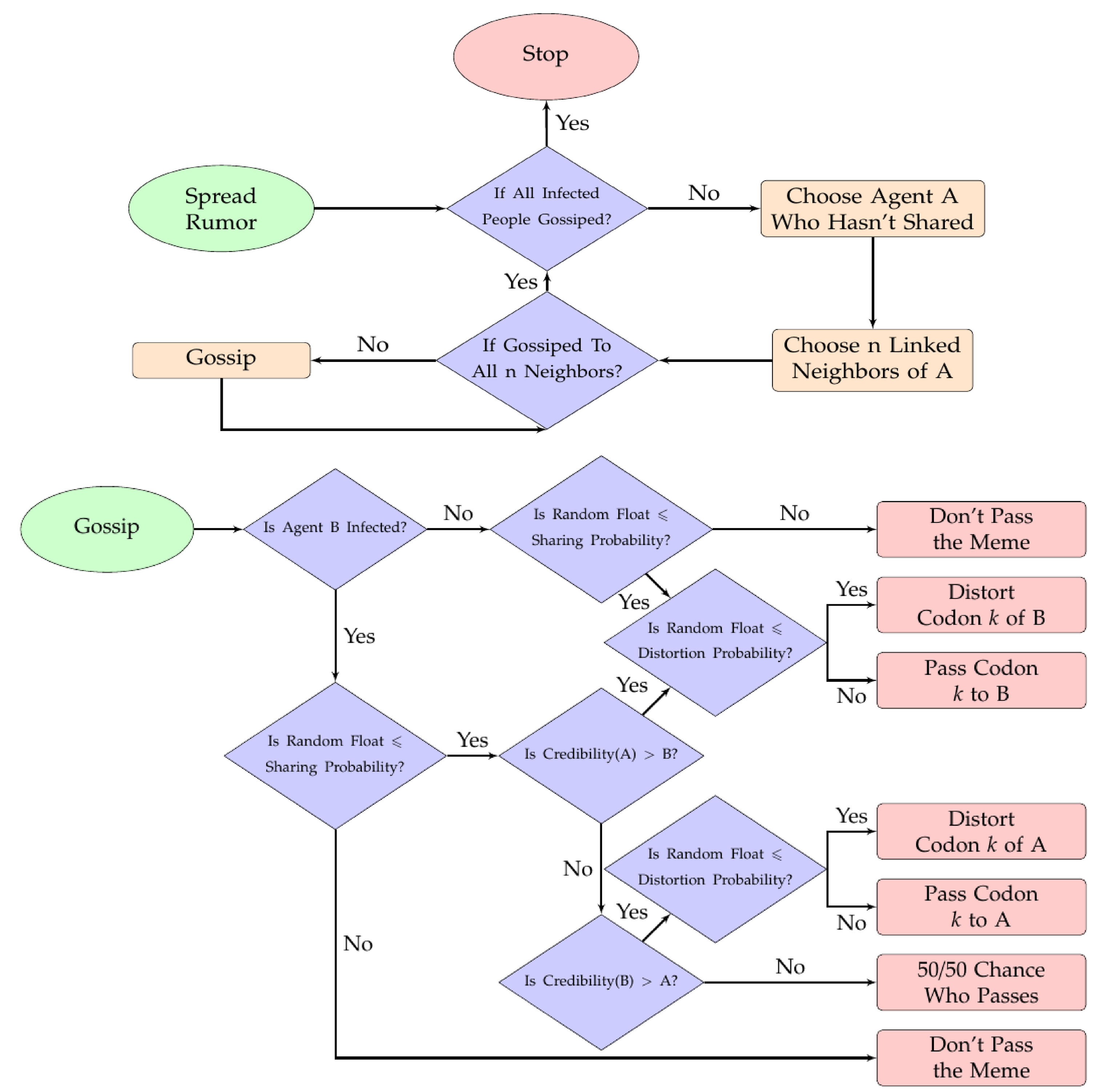
Initialization

- Create agents according to `number-of-students`
- Assign agents truthfulness and relevance values then allocate them to sub-groups
- Those belonging to the same subgroup are linked; those without are labeled "loners"
- Divide rumor based on `max-meme-length`; memes are assigned a relevance value
- Every codon in the initial rumor is set to 1 and given a fitness value
- Define the following parameters: population size, number of initially infected, rumor length, links weights, number of sub-groups, the maximum meme length, and relevancy range
- Input Data: The number of sub-groups and their average sizes are taken from Rhodes College website

Bibliography

- N Difonzo & P Bordia. 2007. "Rumors influence: Toward a dynamic social impact theory of rumor" in *Science of Social Influence: Advances & Future Progress*, Philadephia, PA: Psychology Press.
- T Ireland & RM Neilan. 2016. *Ecological Modeling*, **337**, 2016, 123-136.
- V Tweedle & RJ Smith. 2011. "A mathematical model of Bieber fever: the most infectious disease of our time?" In *Understanding the Dynamics of Emerging and Re-Emerging Infectious Diseases Using Mathematical Models*, Kerala, India: Transw. Res. Netw.

Spread Rumor Procedure



Submodels

- **Setup Network**: Assigns each agent a sub-group, truthfulness, and relevance value. Creates links between agents in the same sub-group. All agents are given a rumor with all zeros except for those who start with the initial rumor.
- **Setup Rumor**: Divides the rumor into memes of length 1 to the maximum meme length. Assigns each meme a relevance value and their codons a fitness value.
- **Sum Links**: Calculates the probability of two agents socializing at least once per tick. Represents the strength of a relationship.
- **Credibility**: Represents the trustworthiness of an agent. Whoever's credibility is higher becomes the source of information when two infected agents communicate.
- **Juiciness**: Represents how relevant each meme is to the respective agent. For each relevance value that is within the relevancy range, 0.5 is added to juiciness.
- **Sharability**: Combines relevancy, relationship strength, and believability to determine the probability of two agents sharing a piece of information.
- **Sharing Probability**: Probability of sharing meme i between agents A and B based on sharability.
- **Distortion Probability**: Probability that codon k is distorted. Combines fitness, truthfulness, and believability. Distortion occurs in increments of 1 (up to 5).
- **Calculate Mutation Measure**: Calculates average value for each codon, k, to evaluate the rumor's evolution. Only samples agents who have heard the codon k.

Conditions

- There are many different network and rumor conditions that can be applied.
- We chose to control the average fitness values, average links, and relevancy ranges.
- The mutation measure, percent infected, and percent fidelity were recorded after every tick.
- Simulations used identical rumors and networks when comparing narrow to broad relevancy ranges.

Fitness	Average Links	Fitness	Average Links
Low	1-40	Low	1-40
Low	40-80	Low	40-80
Low	80-120	Low	80-120
Even Spread	1-40	Even Spread	1-40
Even Spread	40-80	Even Spread	40-80
Even Spread	80-120	Even Spread	80-120
High	1-40	High	1-40
High	40-80	High	40-80
High	80-120	High	80-120
Relevancy Range: Narrow		**Relevancy Range: Broad**	

Mutation Measure Graphs

Below are a few of the density plots for mutation measure with respect to fitness, percent infected, and percent fidelity. The length of each rumor is 20 codons, and the simulations had run for 10 time steps.

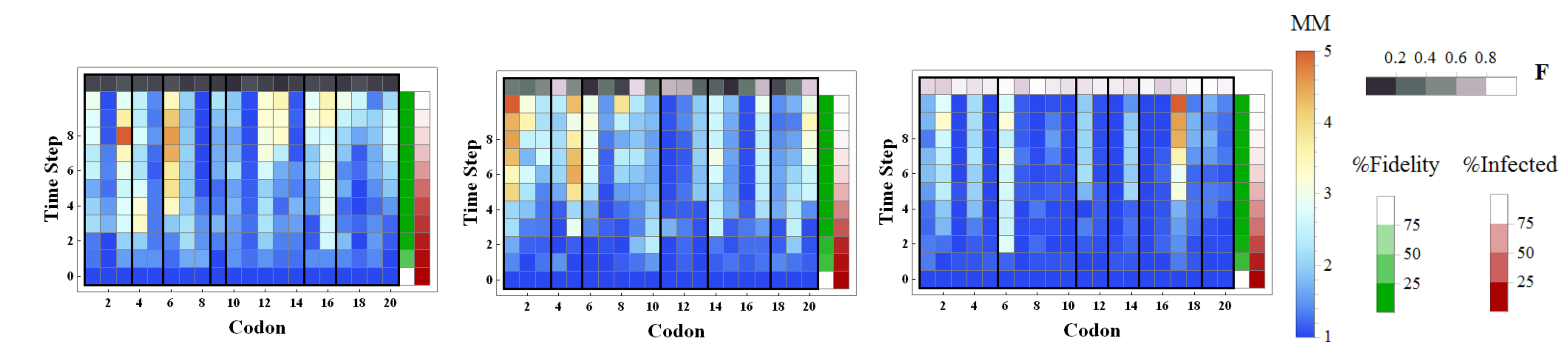


Figure 1: Results from average links between 1-40 and narrow relevancy ranges.

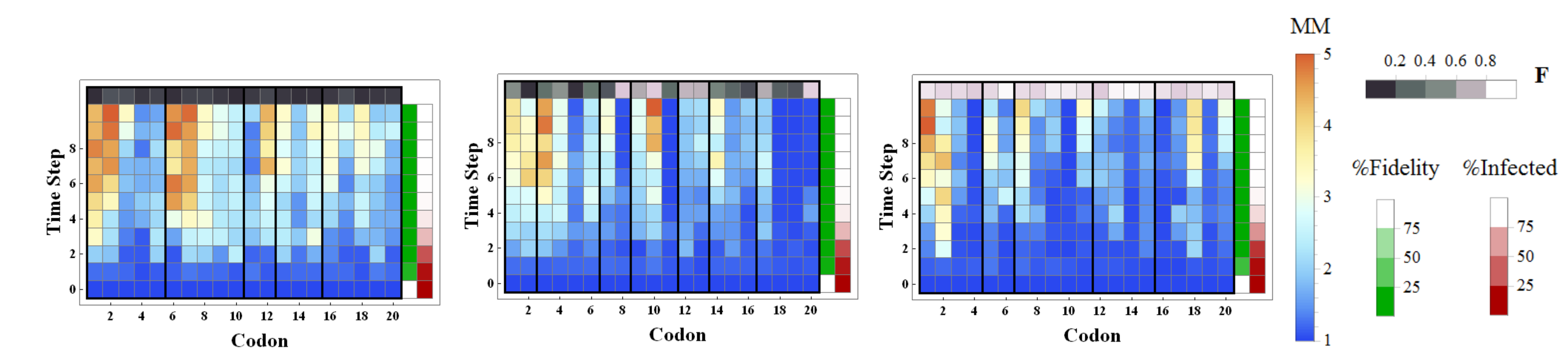


Figure 2: Results from average links between 40-80 and narrow relevancy ranges.

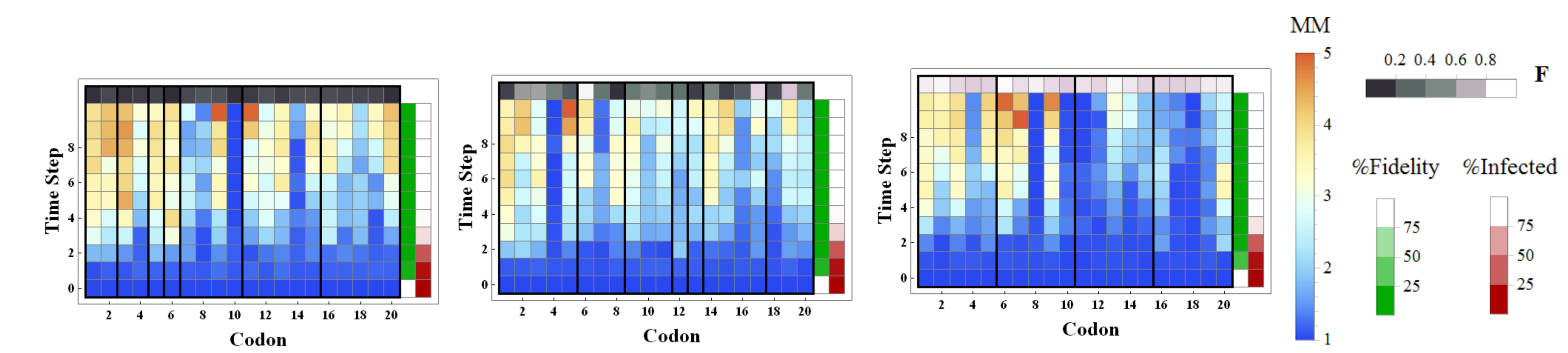


Figure 3: Results from average links between 80-120 and broad relevancy ranges.

Measures

For agents A and B with weight W of social group i:

$$\textbf{Sum Link Weight(A,B)} = \sum_{i=1}^{n} W_i - \sum_{i<j} W_i \cap W_j + \sum_{i<j<k} W_i \cap W_j \cap W_k - \cdots + (-1)^{n-1}\left(\bigcap_{i=1}^{n} W_i\right)$$

$$\textbf{Credibility(A)} = \text{Truthfulness}(A) \times \text{Sum Link Weight}(A,B)$$

For meme i:

$$\textbf{Sharability(i|A,B)} = \frac{\text{Juiciness}(i) + \text{Sum Link Weight}(A,B)}{\text{Average Distortion}(i)}$$

$$\textbf{Sharing Probability(i|A,B)} = \frac{(\text{Sharability(i)})^2}{0.5^2 + (\text{Sharability(i)})^2}$$

$$\textbf{Distortion Probability(k|A,B)} = \exp\left[(\text{Fitness}(i) + \text{Truthfulness}(A) + \text{Truthfulness}(B) + \text{Distortion}(i))^2\right]$$

For codon k:

$$\textbf{Mutation Measure(k)} = \frac{n_{1k} + 2n_{2k} + 3n_{3k} + 4n_{4k} + 5n_{5k}}{c_k}$$

where n_{jk} is the number of people who have a value of j for codon k, and c_k is the total number of people who have a value $j \geqslant 1$ for codon k.

Conclusions

- Based on the mutation measures, we can conclude that the average number of links and relevancy ranges uniquely impact the rate of transmission, while codon fitness values have the greatest impact on rumor distortion.
- Fitness is directly linked to the distortion probability, which is why it had such a big impact on distortion levels.
- The average number of links gives agents more chances to talk to neighbors who have not heard the rumor.
- Higher relevancy ranges prevent memes from being lost. When information stays in the rumor, the mutation measure has more agents to sample from. This could indirectly affect levels of distortion if agents lose information that was already highly distorted.

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