Rumor Spreading Modeling: Profusion versus Scarcity

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Dissemination of rumors

Information: news, opinion, disease, virus, **rumors**

- How to model the propagation?
- Analogies among different kinds of information
- Particular emphasis on epidemical models in the literature
- Compartment models, Meta-population models, Network-based models
- Formal representation, Agent based simulations and Real data analysis
- **Word of mouth** rumors and Online rumors

Outline

1. Context
2. Spatial model of rumor spreading
3. Simulation
4. Conclusion

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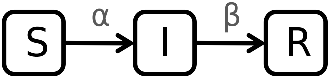
Context

Compartment models

- Rumors studied for years originally in economics, psychology and social sciences (Knapp 1944, Rosnow & Fine 1976)
- Epidemiological mathematics and stochastic solutions (Kermack & Kendrick 1927)
- Agent-based and data driven simulations
- SIR: Three compartments (**S**usceptible **I**nfected **R**ecovered)



Context

Daley Kendall model

Rumor propagation is highly specific

- *Currently circulating story or report of uncertain or doubtful truth* (Oxford dictionnary)
- A kind of contagion process
- Multi-dimensional process driven mainly by socio-psychological elements
- DK Model (Daley & Kendall, 2006): Three compartments (*Ignorant, Spreader and Stifler*)

- DK: principle of novelty
  for an individual likely to tell the story, there is a *reluctance to tell stale news*

Context
SIR and DK Assumptions

Assumptions in SIR and DK

- The population is fully mixed
- Individuals with whom a susceptible individual has contacts are chosen at random into the whole population
- All individuals have approximately the same number of contacts in the same period of time
- The transition from one state to another one relies on a same probability for every individual

Context

Rumor specific properties

On the global scale

- **Longness** since it takes a relative long time for Spreaders to tell the story so that the rumor starts (Zhao al. 2012)
- **Slowness** since the propagation starts slowly and the information spreads in a short time (Kawachi al. 2008)
- **Incompleteness** since the infection does not reach the whole population (Daley and Kendall 2006)
- **Sparseness** since individual neighborhoods are not densely populated by Spreaders (Kawachi al. 2008)

Rosnow and Fine (1976) identified the feature of **scarcity** as a key dimension for rumor spreading: *Rumours arise when information is scarce*

Context
This work

- Word of mouth rumors very difficult to follow, they do not generate data as online rumors that propagate on social media
- Investigation of the **profusion/scarcity** property of the rumor
- New perspective on the context of individuals likely to tell the story themselves once they know it
- A spatiotemporal model of rumor spreading
- What is the most realistic between the two antagonistic properties profusion and scarcity to disseminate a rumor?

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Spatial model of rumor spreading

ODS Model

- A rumor is transmitted by word of mouth from individuals to individuals
- Spatiality, contact, social environment and psychological context are cornerstones of the phenomena
- **ODS model** relies on physical contact and mobility
- Each individual has a location in a world represented by a grid composed of cells
- His/Her neighborhood is composed by the others around him/her
- Individuals are mobile, they create new social contacts when they move
- The diffusion is relying on the induced social network and on individual spreading behaviour
- With spatiality, mobility, dynamicity and socio-psychological aspect, the goal is to better fit the framework to reality

ODS model
Compartments

- **Open-minded** agents are the individuals who have not yet heard the rumor, and, consequently, are susceptible to becoming informed
- **Disseminators** are active individuals that are spreading the rumor
- **Stiflers** are individuals that have got the rumor but are no longer spreading it

The total population size $N = O + D + S$

Spatial model of rumor spreading

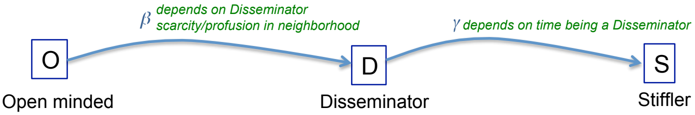
ODS vs SIR and DK

- The aim is to model the spreading of a rumor, thus with the spatial dimension
- Contacts between individuals are not chosen at random and they occur between neighbors only
- Agents are moving, at each time step, the number of contacts for an individual is not a constant
- The probability that a D-individual transmits the information to an O-individual upon contact depends on each individual and varies over time. It is referred as $\beta_k^{OD}(t)$

ODS Model

Transitions

- The potential receiver, and not the transmitter, decides whether or not he will become itself a transmitter:
  Crucial difference with infectious disease spreading
- An **O**-individual a_k becomes himself a **D**-individual according to a function of the rate r_k^D of D-individuals in his neighborhood.
- Two alternative solutions:
  1. ODS_p driven by the *profusion* of information
  2. ODS_s driven by the *scarcity* of information according to the number of D-individuals in the vicinity



Outline

Simulation

ODS Algorithm

1. $t \leftarrow 0$
2. Initialize the parameter $DPeriod$ $\{\gamma \leftarrow \frac{1}{DPeriod}\}$
3. Initialize the population size to N
4. Create N agents
   {each agent have a *state* variable in $\{O, D, S\}$}
5. Place at random the N agents on the grid
   {each agent have a *position* in the 2-D space}
   {each agent have a *heading* which indicates the direction he is facing}
6. Set all the agents O except one which is D
7. **while** $\exists$ one D agent **do**
8.   Call OtoD
9.   Call DtoS
10.   Call walk {ask all agents to move}
11. $t \leftarrow t + 1$
12. **end while**

Simulation

Transmissibility potential

To report if the invasion will succeed or not:

Reproductive ratio $R_0 = \frac{\beta \times N}{\gamma}$ that is the number of secondary infections that result from a single Infected individual in a fully Susceptible population

ODS_s results are consistent with the *longness* feature

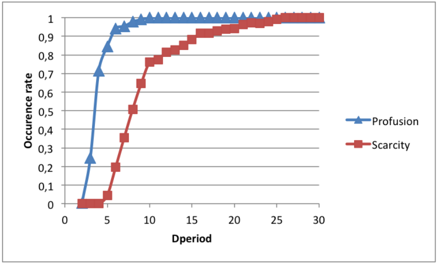
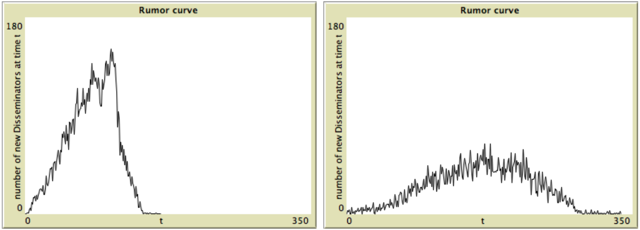


Figure : Probability for a rumor to occur plotted against *Dperiod*

ODS model

Rumor curve

Rumor curve as an epidemic curve: ODS_s process is starting much slower and has a smaller amplitude than in case of profusion



(a) (b)

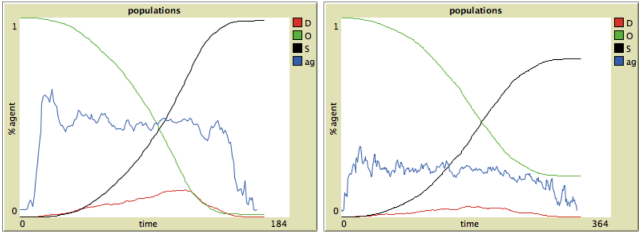
Figure : Rumor curve ($Dperiod = 10$), profusion (a) scarcity (b)

ODS model

Number of individuals in each compartment

At the end of the process, with ODS_s there remain individuals that are not Stiflers

Consistent with the incompleteness feature



(a) (b)

Figure : Proportion of individuals in each compartment as a function of time ($Dperiod = 10$), profusion (a), scarcity (b)

ODS model

Spatial distribution of compartments

D-aggregation index

$ag_D(t) = \frac{1}{|D|} \sum_{k \in D} p_k^D(t)$

where $p_k^D(t)$ can be interpreted as the profusion of disseminators around an individual a_k.

Low values of $ag_D(t)$ means that D-individuals will be spread over the world

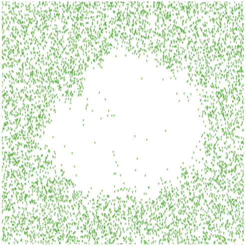
High values correspond to configurations with more homogeneous patterns of D-individuals

D-aggregation index evolution: blue curve

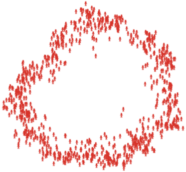
ODS model

Spatial distribution of compartments

Profusion



(a) $t = 70$



(b) $t = 70$

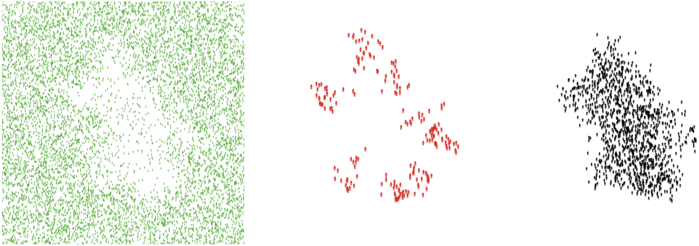
(c) $t = 70$

Figure : Spatial distribution of compartments ($Dperiod = 10$) with profusion and O-persons (a), D-persons (b), S-persons (c)

ODS model

Spatial distribution of compartments

Scarcity



(a) $t = 120$ (b) $t = 120$ (c) $t = 120$

Figure : Spatial distribution of compartments (*Dperiod* $= 10$) with scarcity and O-persons (a), D-persons (b), S-persons (c)

Consistent with sparseness

Conclusion

- We have proposed a model of rumor diffusion that integrates the local context of individuals making the phenomenon
- Agent-based simulations have shown that scarcity induces characteristic features of a rumor identified as longness, slowness, incompletness and sparceness
- Next step will consider an explicit social network like a scale free network