

Information Diffusion summary

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Information Diffusion

- **Introduction**
- Basics of Information Diffusion
- Social Network Diffusion Models
 - Ising Model
 - Epidemic Diffusion Models
 - Cascade Models
 - Threshold Models
 - Game Theory Models
 - Nature-Inspired Model Influence Models
 - Influence Models
- Applications of Information Diffusion

Introduction

- The concept of diffusion is widely used in many fields, including physics, sociology and social media analysis.
- Diffusion and label propagation are two closely related research fields, since label propagation can be regarded as an information diffusion process over a graph.

Diffusion in Physics

Molecular diffusion refers to the motion of liquid or gas molecules, due to thermal energy dissipation, the rate of which is dependent on temperature, viscosity and particle mass. This rate is described by **Fick's second law**:

$$\frac{\partial \varphi}{\partial t} = D \left(\frac{\partial^2 \varphi}{\partial x^2} + \frac{\partial^2 \varphi}{\partial y^2} + \frac{\partial^2 \varphi}{\partial z^2} \right).$$

Diffusion in Sociology

- Diffusion is the procedure through which an innovation, is spread and adopted by the members of a social system. The parameters are compatibility, complexity, trialability and observability.
- A social system is defined as “a set of interrelated units that are engaged in joint problem-solving to accomplish a common goal.”

Diffusion in Social Media

- Information cascades in a network of individuals occur as information or behaviors spread from node to node through the network.

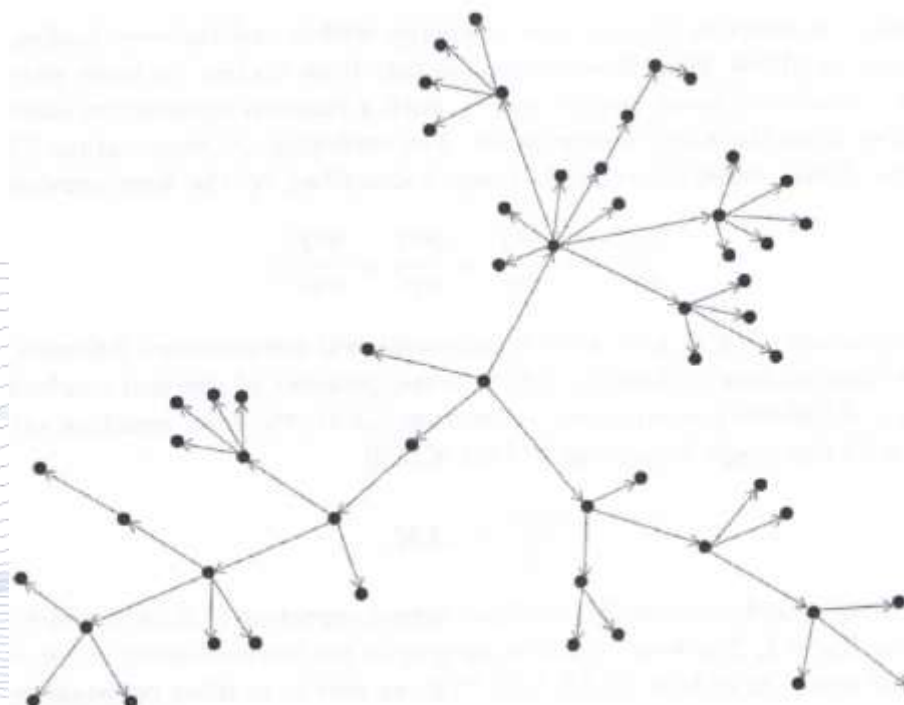


FIGURE 5.4.1: Information cascades in a social network.

Diffusion in Social Media

The underlying mechanisms of information diffusion in social networks can be useful to:

- track the evolution of specific topics,
- prevent misinformation and
- optimizing marketing campaigns.

The study of information diffusion cascades in social networks is an active research field.

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Basics of Information Diffusion

- **3 Basic Factors**

- *Sender(s)* : A sender or a small set of senders that initiate the information diffusion process.
- *Receiver(s)* : A receiver or a small set of receivers that receive diffused information. Commonly set of receivers is much larger than the set of senders and can overlap with the set of senders.
- *Medium*: This is the medium thru which the diffusion take place.

Basics of Information Diffusion

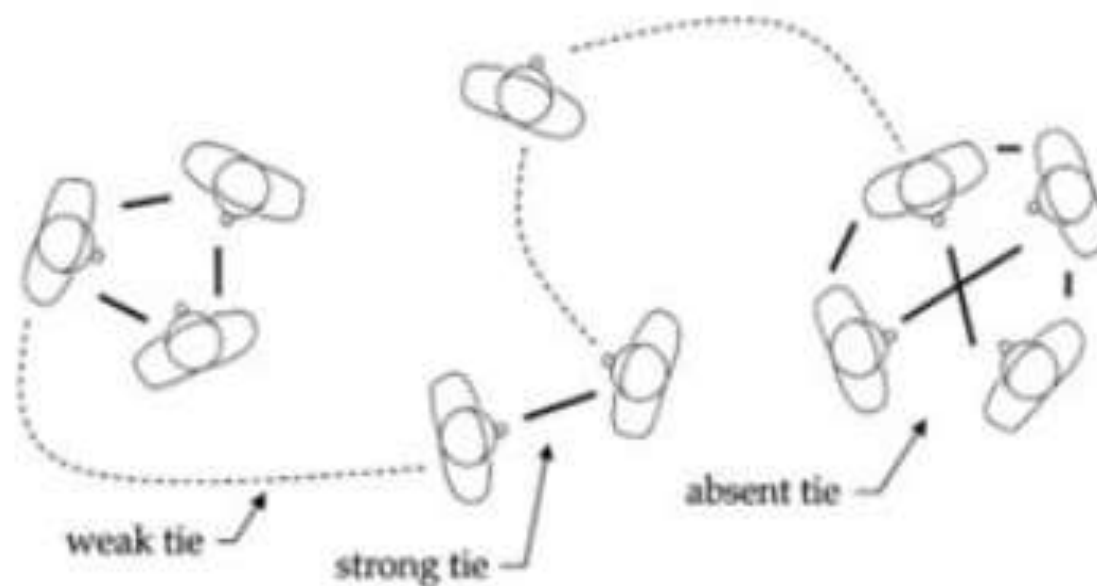
- **Social Network as a Graph**
- To explain social networks, we must focus on the following definitions:
 - *Interpersonal ties*
 - *Triadic Closure*
 - *Bridges*

Basics of Information Diffusion

- **Social Network as a Graph : Ties**
- The ties can be divided into 3 different types based on the strength of interaction.
 - *Strong ties*: the stronger links, for example two friends.
 - *Weak ties*: the weaker links, for example, two acquaintances.
 - *Absent ties*: the one for which we have no information.

Basics of Information Diffusion

- **Social Network as a Graph : Ties**



Chakraborty, Anwesa, et al. "Application of graph theory in social media." International Journal of Computer Sciences and Engineering 6 (2018): 722-729.

Basics of Information Diffusion

- **Social Network as a Graph : Triadic Closure**

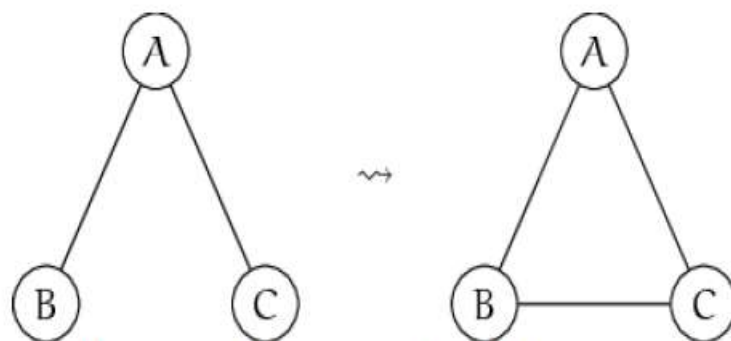


Figure 4: Open triad and close triad

Chakraborty, Anwesha, et al. "Application of graph theory in social media." *International Journal of Computer Sciences and Engineering* 6 (2018): 722-729.

Basics of Information Diffusion

How does the tie strength influences diffusion?

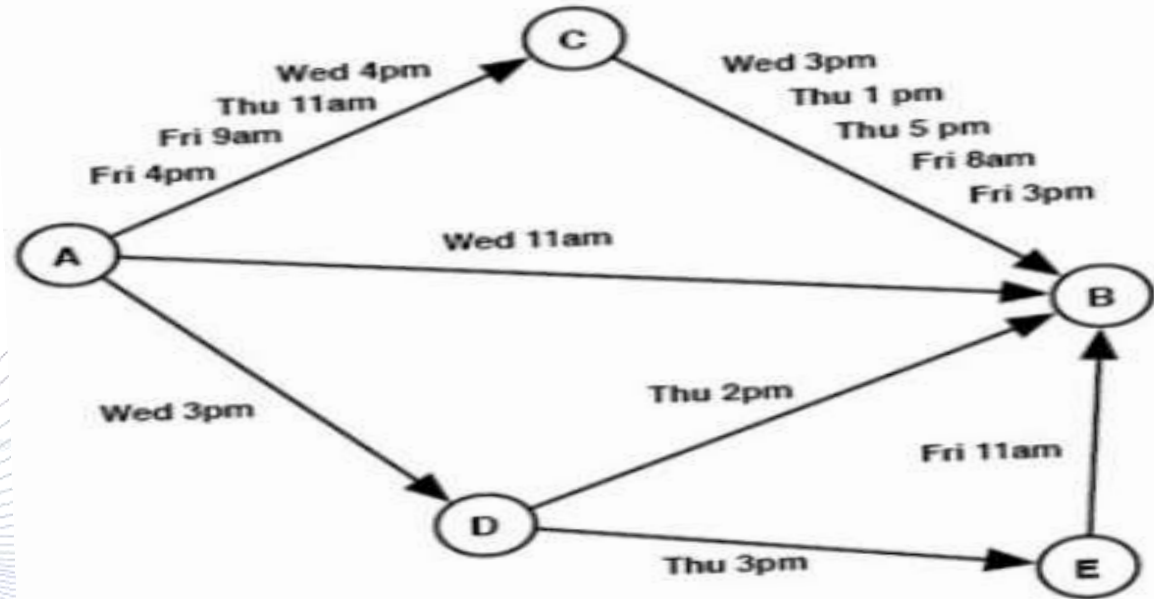
Finding a job through a contact that one saw:

- 2 times per week 16.7%
 - Occasionally 1-2 per month 55.6%
 - Rarely 27.8%
- M.S. Granovetter: The Strenght of weak ties, AJS 1973

Basics of Information Diffusion



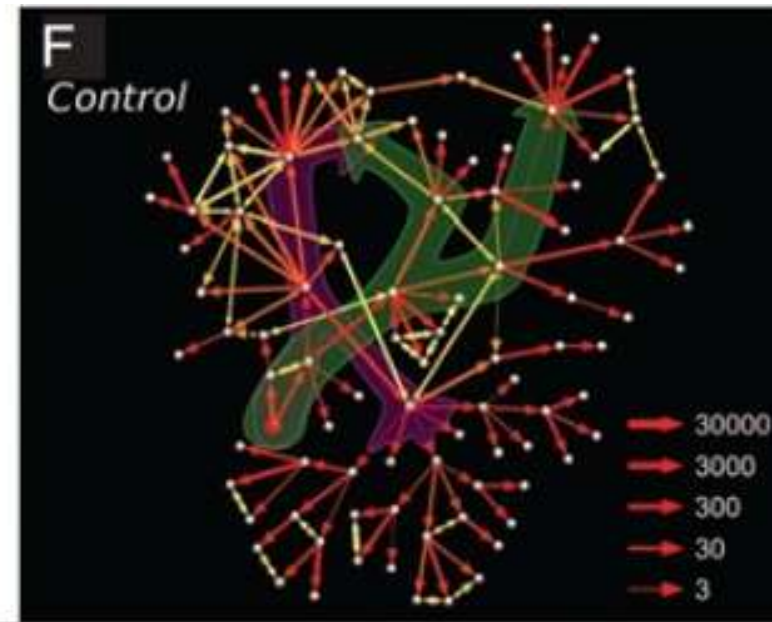
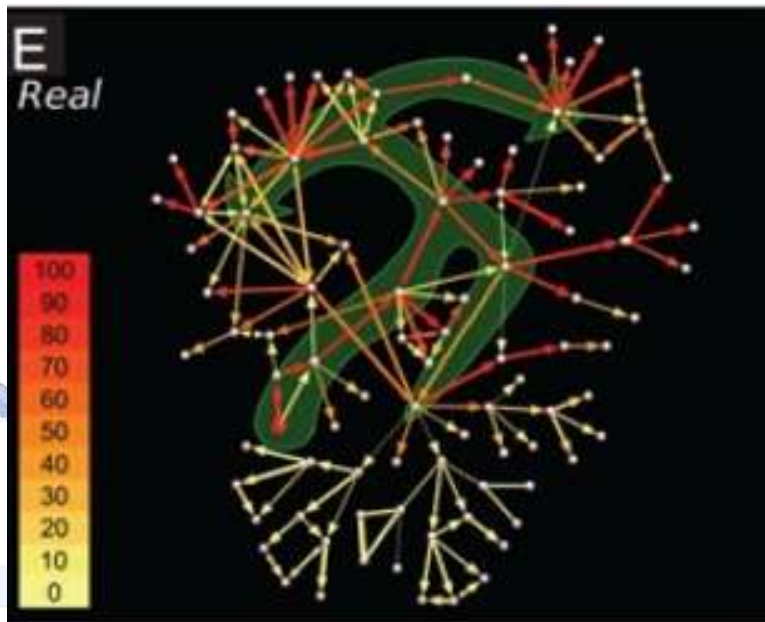
Which paths yield the most up to date info?



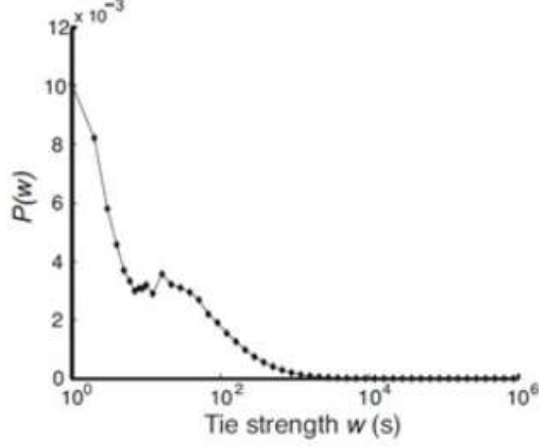
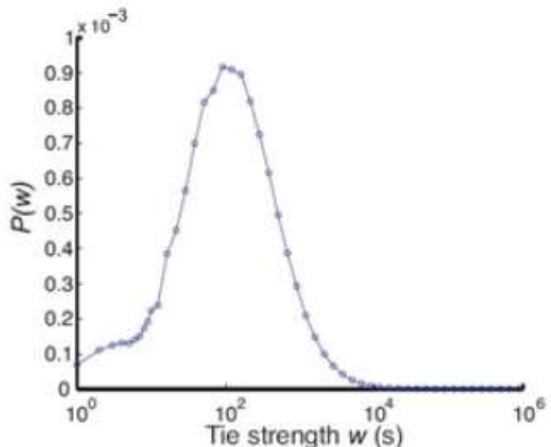
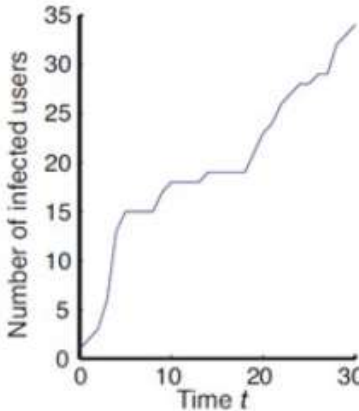
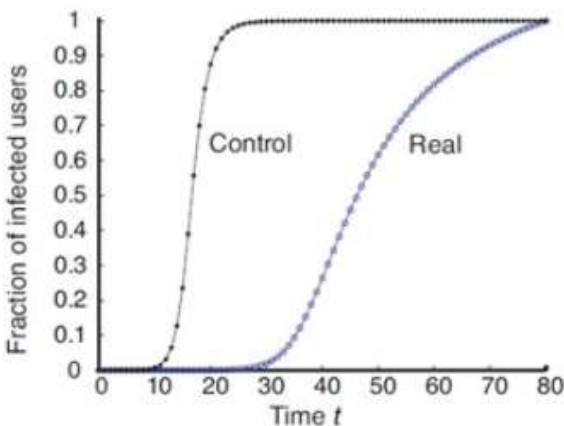
Kossinets, Watts, Kleinberg KDD 2008.

Basics of Information Diffusion

- Structure and tie strengths in mobile communication networks:



Basics of Information Diffusion

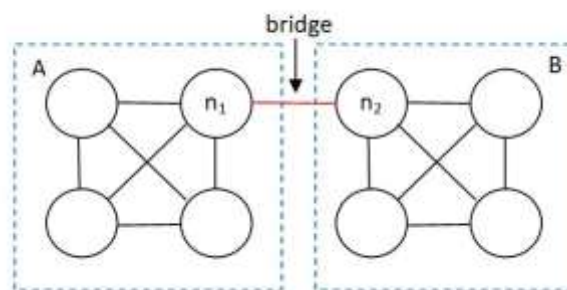


Slow infection of localized strong ties

Basics of Information Diffusion

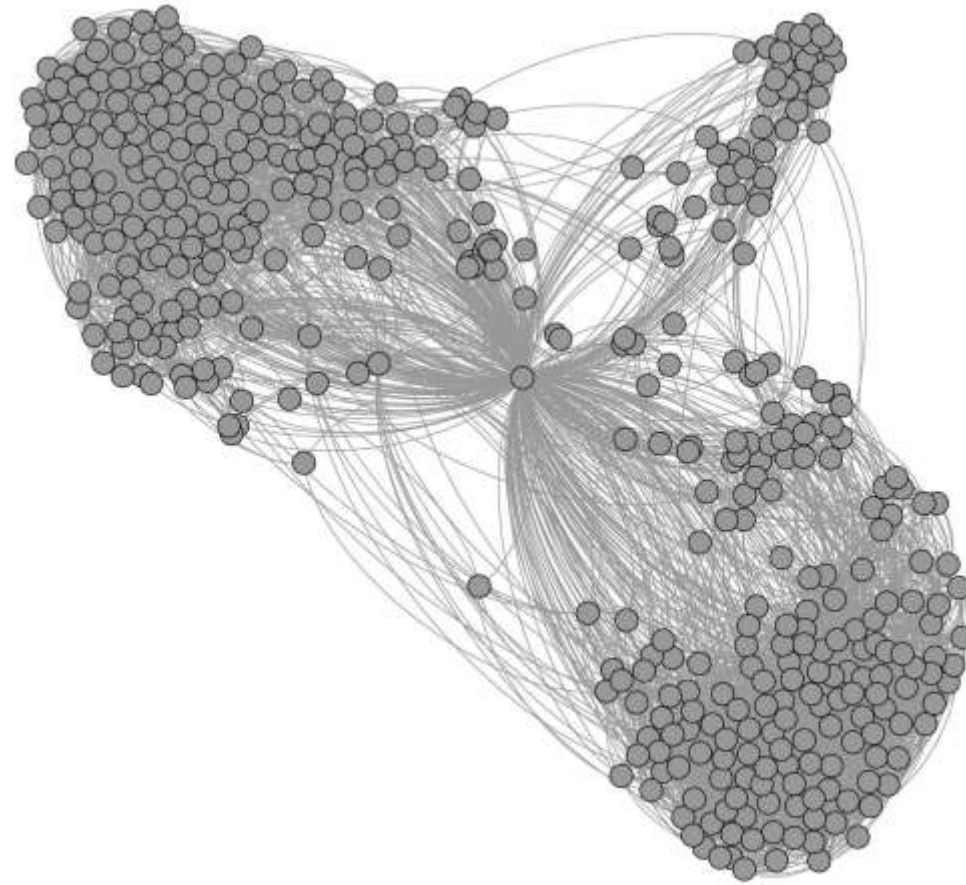
Social graph bridges

- Let the E and F make up a social networking graph, m_1 is in E, m_2 is in F, and there is a social tie r between m_1 and m_2 .
- If r were to be removed, E and F would become disconnected components of the graph.
- This means that r is a bridge if this tie is the only way information can move from E to F.



[https://en.wikipedia.org/wiki/Bridge_\(interpersonal\)](https://en.wikipedia.org/wiki/Bridge_(interpersonal))

Basics of Information Diffusion

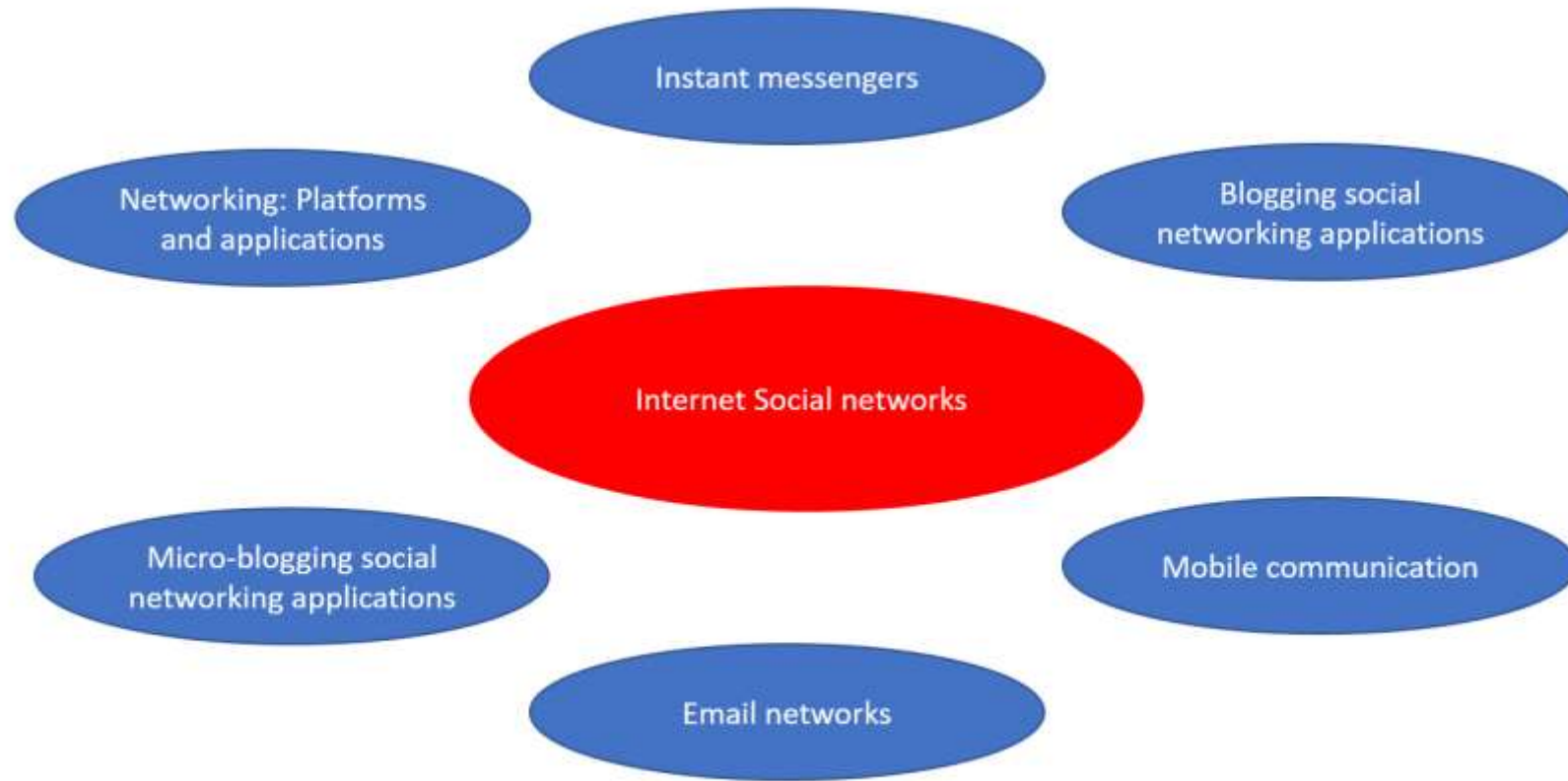


Social graph person-bridge between three person clusters.

Basics of Information Diffusion

- **Online Social Networks**
- Online social networks are very important and increase the dissemination of new information.
- We can Divide the internet social networks into the following categories: Mobile communication, Blogging social networking application, Instant messengers, Email networks, Micro-blogging social networking applications, Networking: Platforms and application

Basics of Information Diffusion



Basics of Information Diffusion



•Social Influence

- Messaging is the content generated by the members of an online social network.
- This flow is a sequence of decisions, with later people following the actions of previous people.
- This process is also called social influence.
- Based on the influence of social influence, information can be disseminated throughout the network through the principles of herd behavior and informational cascade.

Basics of Information Diffusion

- **Social Influence**

- *Information Cascade*: A behavior of information adoption by people in a social network resulting from the fact that people ignore their own information signals and make decisions from inferences based on earlier people's actions

- *Herd behavior*: A social behavior occurring when a sequence of individuals make an identical action, not necessarily ignoring their private information signals

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Ising Model

- The Ising Model is a tool used to describe the phase transition of matter.
- Through phase change, the material produces new structures and physical properties.
- The phase change system is generally a strong interaction between molecules, also known as synergistic systems.
- It is important to derive an expression of individual participation " $p(t)$ " in specific research.

Ising Model

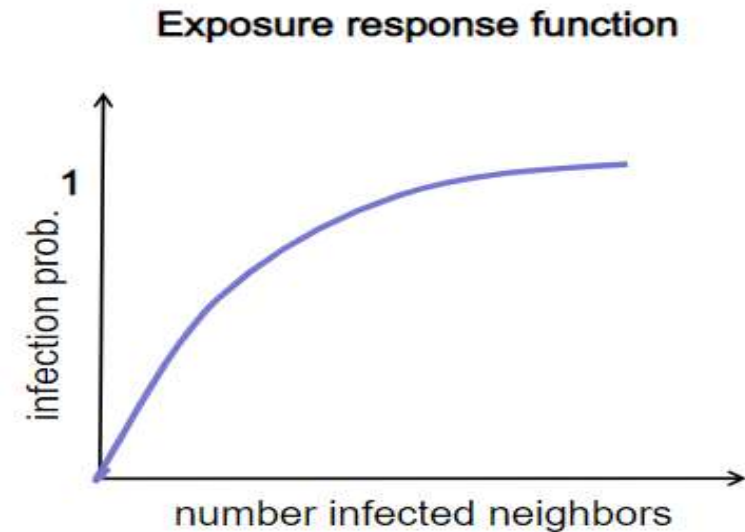
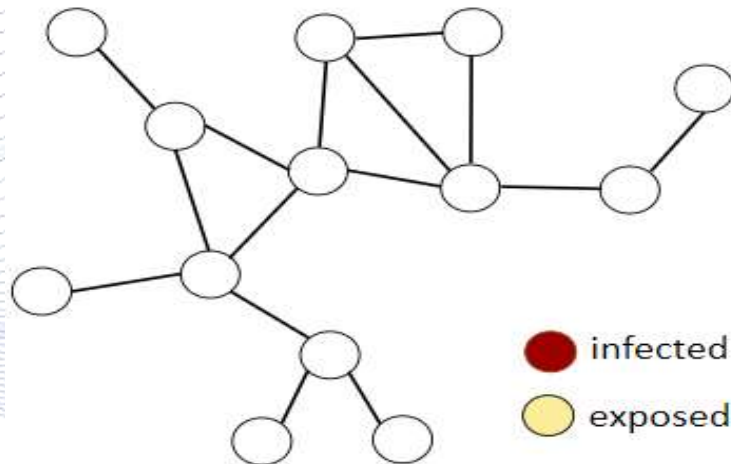
- **Herd behavior**
- This model focused on the influencing factor of Herding behavior on the social network with applications in the perspective of marketing, vote forecasting and maximum social impact.
- Many models focused on the influencing factor of Herding behavior on the social network with applications in marketing, vote prediction and maximum social impact.

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Epidemic Diffusion Models

- The mathematical models most commonly used to disseminate information are epidemic models.
- Infected nodes propagate contagion to susceptible neighbors with probability p (transmissibility or virality of contagion).



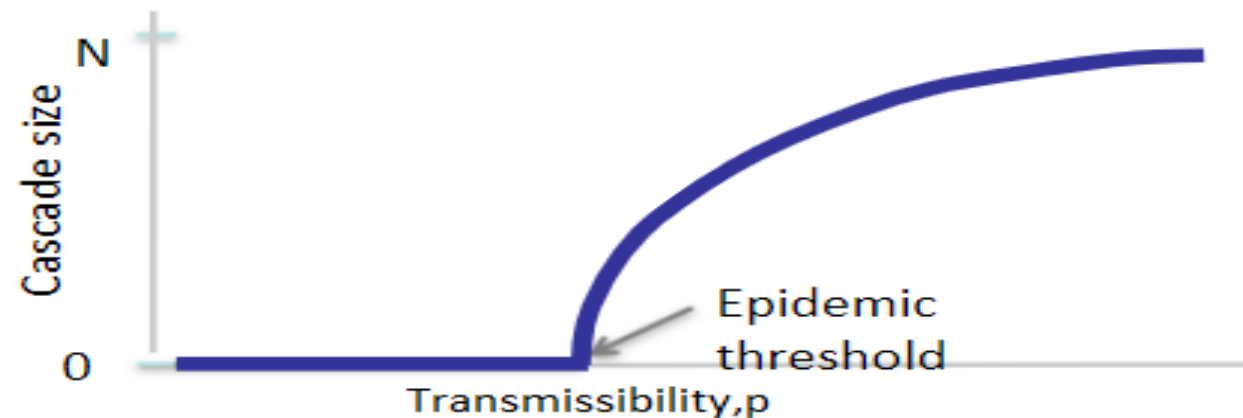
Epidemic Diffusion Models

Epidemic threshold t .

- For $p < t$, localized cascades.
- For $p > t$, global cascades.

Epidemic threshold depends on topology only: largest eigenvalue of adjacency matrix of the network.

-True for every network.



Epidemic Diffusion Models

- Classical works by Kermack and McKendrick
- These epidemic models find application in various other contagious processes, such as:
 - Epidemiology
 - Dissemination of information,
 - Dissemination of innovation,
 - Promotion of commercial products
 - Dissemination of political movements.

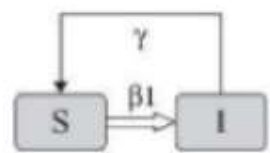
Epidemic Diffusion Models



- People are divided into different compartments in the epidemic models.
- *S(susceptible)*: The susceptible state, represents people in this state is unaware of the information and would be infected in the future
- *I(Infected)*: The infected state, represents people in this state have already aware of this information and will transmit it to others
- *R(Recovered)*: The recovered state, represents people in this state have already aware of this information, but are not care about it, thus they will not transmit the information to others any more.

Epidemic Diffusion Models

- **SIS model**
- In this model users can return to the S state, in contrast to the SI model which does not allow the treatment of infected users after their submission have been infected
- In other words, μ represents the proportion of the infected users that have been cured in the total population.



Epidemic Diffusion Models

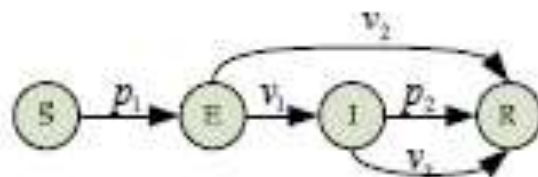
- **SIR model**
- It differs from SI and SIS model, the authors gives a recovered state (R) and respectively we claim that $S + I + R = N$
- Individuals in S state would be infected by the I state individuals with probability β , whereas the I state individuals would recover to R state with a recovery probability μ .



<https://www.slideshare.net/SocialMediaMining/social-media-mining-chapter-7-information-diffusion>

Epidemic Diffusion Models

- **Epidemic Models in Social Networks**
- The *SEIR model* : This method is based on the SIR model by adding Exposed nodes on it. The model describes the process of information propagation based on a dynamical evolution equation, analyzing the impact of user login frequency and number of friends on information diffusion.



<https://www.slideshare.net/SocialMediaMining/social-media-mining-chapter-7-information-diffusion>

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Cascade Models

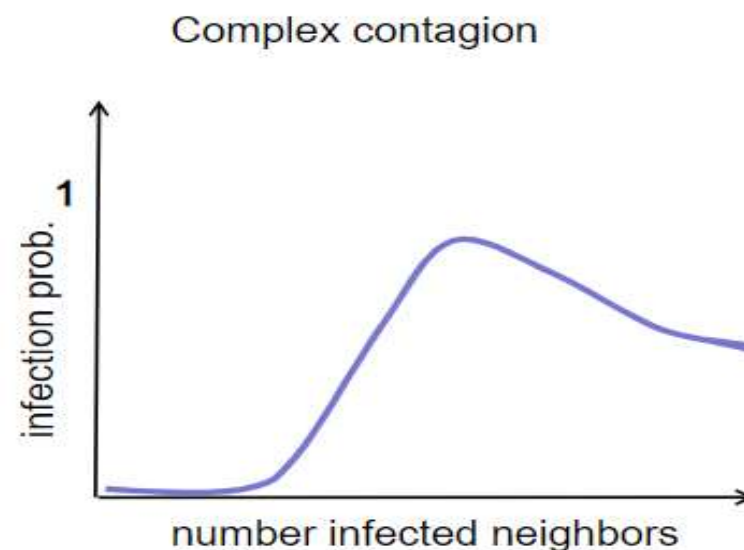
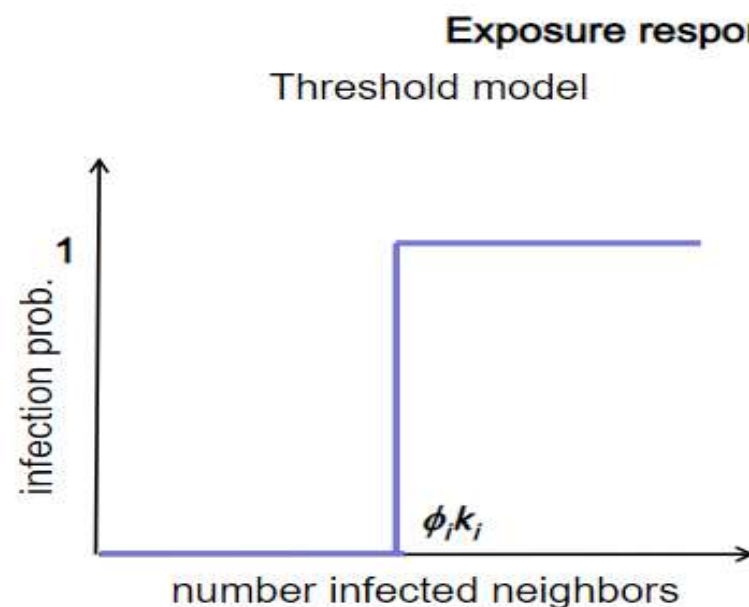
- **The *Independent Cascade(IC) model***
- Is mainly used for prediction and influence research.
- When a node v is inactive can be activated by the active node u independently with a probability of P_{ij} at specific time t .
- If node v is activated, then it will be an active node at time t .
- Regardless of whether the u activates v at time t , v will not be activated by u at the following time.

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Threshold Models

- Complex response: inflection requires multiple exposures.
- Non-monotonic exposure response



Threshold Models

Linear Threshold Model

- The LT model during the influence spreading process focuses on threshold behavior.
- As the IC model, this model is used to study influence in social networks.
- Consider a set of N nodes or agents connected by M undirected edges.

Threshold Models

Linear Threshold Model

- The state of an agent i at time t is described by a binary variable $s_{i(t)} = \{0,1\}$. In this set the 1 represents the “active” state and 0 the “inactive” one.
- At time $t = 0$, a fraction ρ_0 of randomly selected agents is initialized in the active state.

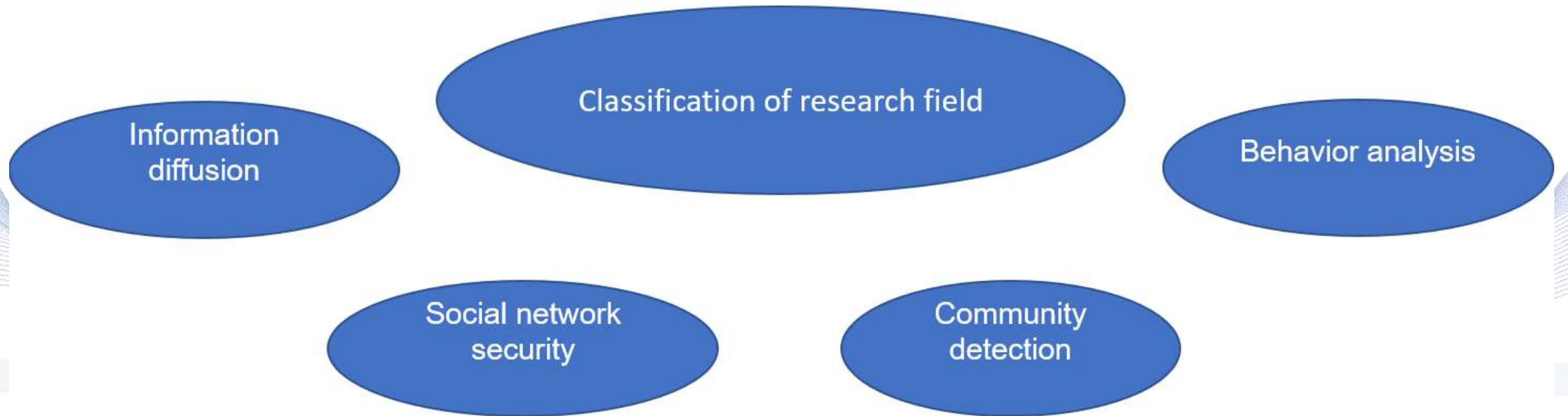
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Game Theory Models

- Game theory is the study of mathematical models of strategic interaction among rational decision-makers.
- It has applications in all fields of social science, as well as in logic, systems science, and computer.
- Most game theory applications in social network research is about individuals' behaviors and the strategic interactions among these individuals.

Game Theory Models



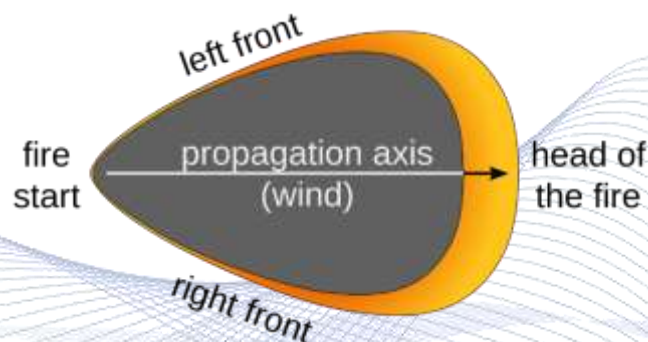
Classification of game theory models research field

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Nature-inspired model Influence models

- Complex systems like biological, communication and social networks can be modeled as graphs. Many attempts have been made to model information diffusion using nature-inspired algorithms.



https://en.wikipedia.org/wiki/Wildfire_modeling

- A forest-fire algorithm has been used to study information diffusion on Twitter and modify it to find the actual spreaders of information.

Nature-inspired model Influence models

- The traditional forest-fire model defined for a cell automata consists of three states:

1. *Empty*
2. *Tree*
3. *Fire*

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Influence Models

- Information diffusion based on influence is divided into three categories :

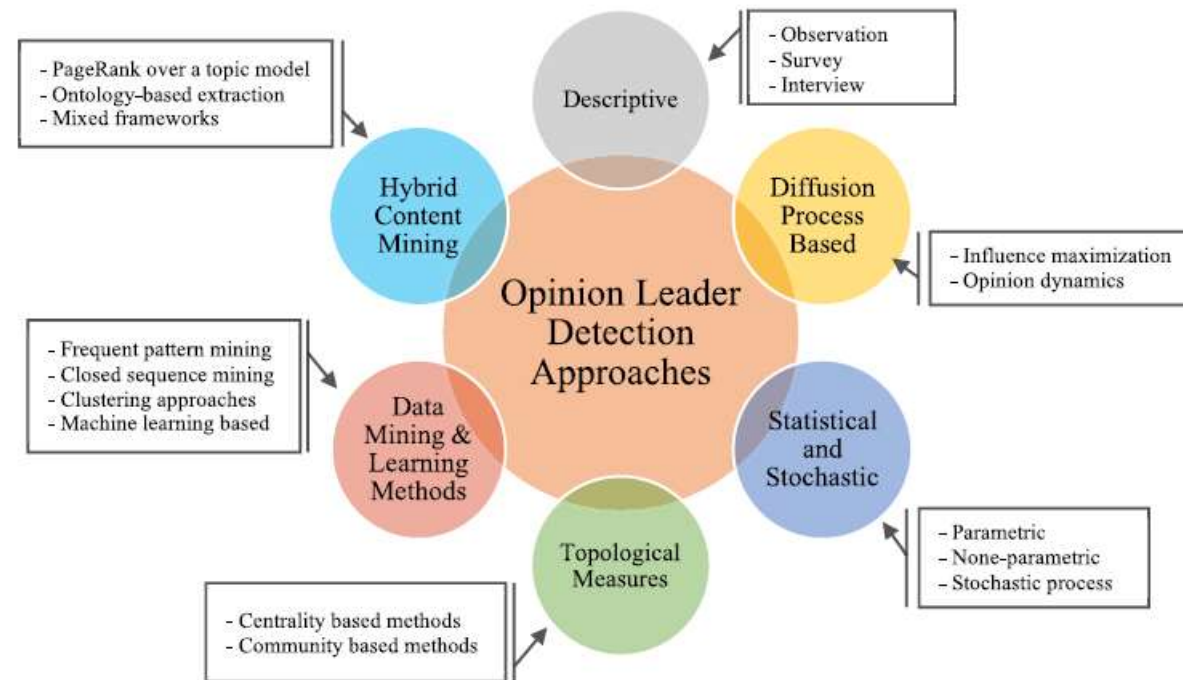
1. *Individual Influence*
2. *Community Influence*
3. *Influence Maximization*

Influence Models

Individual Influence

- A social network as a basic communication platform directly connects online users and binds them to the possibility of exchanging information.
- Based on the interactions, users can influence or be affected by the opinions of others opinion leader sare users who can influence and shape the views of others.
- The problem of identifying opinion leaders, due to its wide application in reality, is very important. The problem has been attracting many studies over recent years.

Influence Models



Opinion leader detection methods.

Influence Models

Community Influence

- Common properties of a community are an important research area.
- A community is a subset of the network where its members have common habits and interests and the links between them are close.
- Also, the structure of the communities remains relatively stable in contrast to the structure of the overall network.
- Many methods have been proposed to solve this issue, mainly including links and attributes.

Influence Models

Influence Maximization

- The objective is to influence the largest possible population within a social network, related to finding the initial set of labeled data that optimize propagation.
- Influence maximization has application to viral marketing, network monitoring, rumor control, and social recommendation.

Influence Models

Influence Maximization

- The most important approaches of influence maximization algorithms are:
 - Simulate based-approaches
 - Proxy-Based Algorithms
 - Sketch-based approaches approximation algorithmic framework.

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- **Applications of Information Diffusion**

Applications of Information Diffusion

- Rumor-diffusion.
- Cross-Media Information Diffusion.
- Viral marketing.
- Emergency situation management.
- Collaborative filtering.
- Citation networks.

Applications of Information Diffusion

Rumor Propagation

D–K model:

- Individuals are assumed to be in one of those three states: ignorant (S , susceptible state in SIR), spreader (I , infected state), and stifler (R , recovered state).
- The spreader individuals might infect the ignorant individuals with some probability.

Applications of Information Diffusion

Cross-Media Information Diffusion

- Online social media play a key role in the spread of trends, news, and opinions. Increased user activity in social media is observed during important events.
- Such elevated activity reflects people's immediate reactions to the broadcasted event, and the process of information / concept diffusion from broadcast to social media.

Applications of Information Diffusion

Viral Marketing

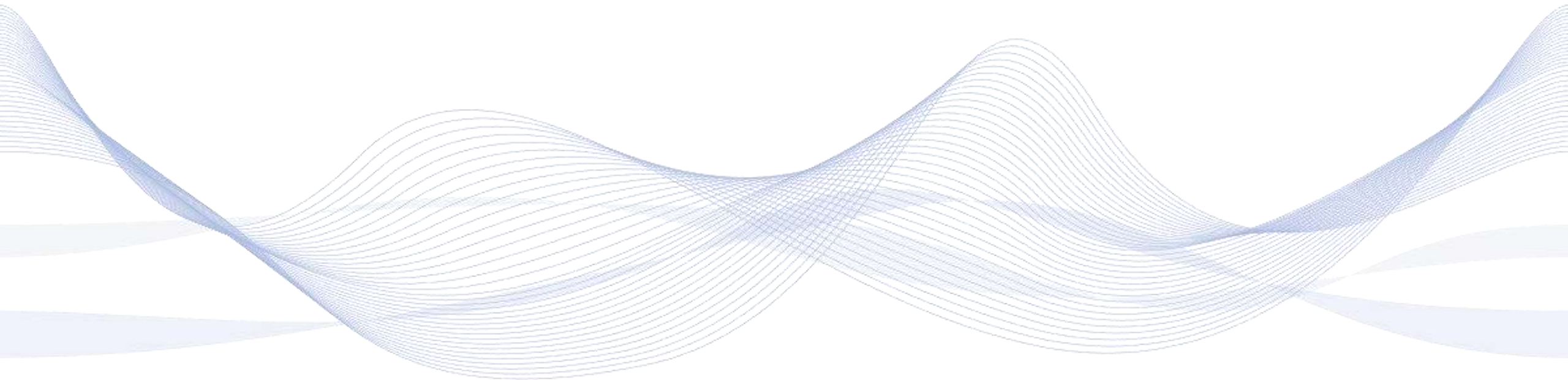
- Viral marketing is a marketing method that uses social networks. It is based on people who have a big influence on their relatives and friends in online social networks (Facebook, Twitter).
- Researchers are trying to measure the influence of these people from nodes and propagation ratios on online social networks.
- Companies invest in and target these influencers because marketing through them will have a big impact on their products and greater profit.

Applications of Information Diffusion

- Information diffusion methods find application in ***emergency situation management***, where mass media function as channels for information spread.
- Threshold, diffusion and cascade models are utilized.

Applications of Information Diffusion

- Diffusion methods are used in **collaborative filtering** algorithms found in recommendation systems, in order to make predictions about the interests of a user.



Applications of Information Diffusion

- Information diffusion is also observed in ***citation networks***.
- Analyzing structural features of information paths through these networks, and impact on the information flow, variations can be found in information diffusion for specific subsets of citation networks.

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Q & A

Thank you very much for your attention!

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