DCS/CSCI 2350
Social & Economic Networks

How do diseases, behavior, opinion, technology, etc. propagate in a network?

Cascading Behavior in Networks

Reading: Ch 19 of EK

Mohammad T. Irfan

2

How Does Our Social Network Influence Our Behavioral Choices?

NSF Core Research Grant

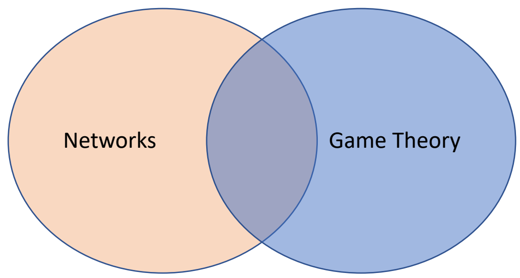
"No man is an island" wrote the poet John Donne in 1624, meaning whether we like it or not, we are all connected. It's an assertion that rings truer than ever in today's networked world, and a it's a central theme of the research currently being done by computer scientist Mohammad Irfan and his colleagues.

Assistant Professor of Digital and Computational Studies (DCS) and Computer Science (CS) Irfan recently helped to secure around half a million dollars in funding for an exciting multiyear project exploring human interactions in networks. The research could have implications for many fields, he says, from public health to energy pricing to finance to the analysis of congressional voting patterns.

The award was made by the National Science Foundation (NSF) and done in collaboration with Luis E. Ortiz of the University of Michigan—Dearborn, for a multiyear research initiative. It's all part of a core NSF program called Information and Intelligent Systems, says Irfan, who is the project director (while Bowdoin is the lead organization.)

3

My recent research



4

My recent research

- Influence in networks (with Phillips'19 and Ostertag-Hill'20)
- Power of context in influence networks (with Gordon'17)
- Influence in residential segregation

http://mtirfan.com/research

5

My recent research

- Congestion games
- Emergence of roles in multi-agent asset markets (with Albers'23)
- Cascades and overexposure (with Hancock'21 and Friel'22)

http://mtirfan.com/research

6

Diffusion of innovations

- Studied in sociology since 1940s
- One's choice influences others

7

Types of diffusion

- Indirect/informational effects – social learning
  - Photo/video going viral
- Direct-benefit effects
  - Technology adoption– Xbox/PS5, phone, fax, email, FB

8

Examples

- Adoption of hybrid seed corn in Iowa
  - Ryan and Gross, 1943
- Adoption of tetracycline by US doctors
  - Coleman, Katz, and Menzel, 1966

9

Shared ingredients in examples

- Indirect effects
- Adoption was high-risk, high-gain
- Early adopters had higher socioeconomic status
- Social structure was important– visibility of neighbors' activity

10

Success factors of diffusion

Diffusion of Innovations– Everett Rogers (1995)

- Complexity
- Observability
- Trialability
- Compatibility

11

#TheDress

(February 2015)

13

Chris Murphy · @ChrisMurphyCT
I know three things: 1) the ACA works; 2) climate change is real; 2) that dress is gold and white.
3 days ago ·

Mark Takano · @RepMarkTakano
Just asked my Legislative Director at 10:30 pm to draft a House resolution tomorrow about the dress being black and blue. AMA.

Anna Kendrick · @AnnaKendrick47
If that's not White and Gold the universe is falling apart. Seriously what is happening????

Demi Lovato · @ddlovato
Hold on.... So people actually see white and gold....??!! □□
3 days ago ·

Julianne Moore · @_juliannemoore
@mindykaling @bjnovak what's the matter with u guys, it's white and gold.
3 days ago ·

14

Viral Facebook post (2013)

15

Hush puppies (1995)

16

Next

- Modeling diffusion
- Connection with the things we know
  - The strength of weak ties
  - Clustering

20

Threshold models for diffusion

21

Precursor: Granovetter's model

- Mark Granovetter's threshold model of collective behavior (1978)
- An individual will adopt an action if at least a certain number (threshold) of other individuals adopt it
  - Riot example
  - General networks and distribution of threshold

22

- Collective behavior: Relatively spontaneous, unstructured, extra-institutional behavior of a fairly large number of individuals. (Goode)
  - Residual field in sociology
- Collective action: People acting together in pursuit of common interests. (Tilly)
  - 1990s to date

23

Contagion Model

Stephen Morris, 2000

25

Initial adopters

Granovetter's model: individuals with 0-threshold are the initial adopters

vs.

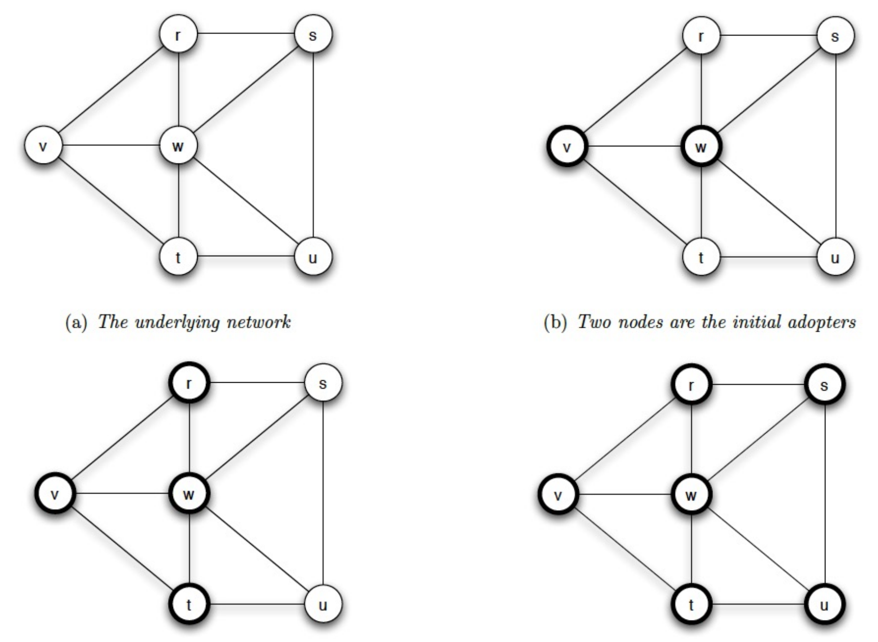
We can set initial adopters <u>without any regard for their threshold</u> (modeling assumption by Kleinberg et al.)

28

Example: switching from B to A

- Initially, everyone does B
- Payoff parameters: b = 2, a = 3
- Threshold for switching to A, q = 2/5 = 40%
- We will set two initial adopters of A and "play out" the diffusion

30



(a) *The underlying network*

(b) *Two nodes are the initial adopters*

(c) *After one step, two more nodes have adopted*

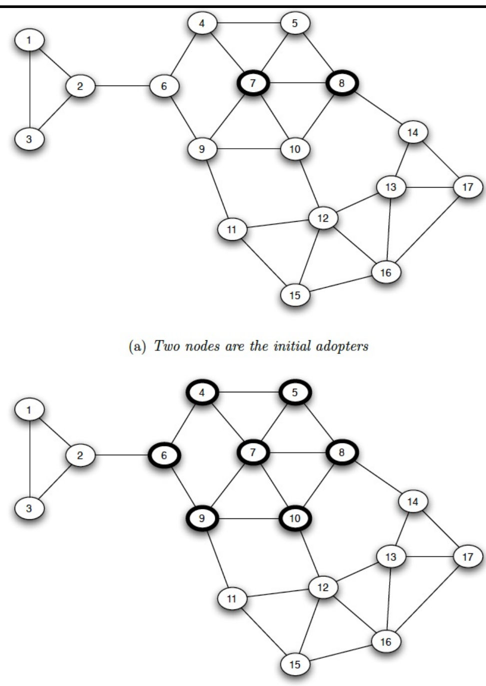
(d) *After a second step, everyone has adopted*

31

Complete cascade

- Def. A set of initial adopters causes a "complete cascade" if everyone adopts the new action at the end of diffusion.
  - Always happens?

32



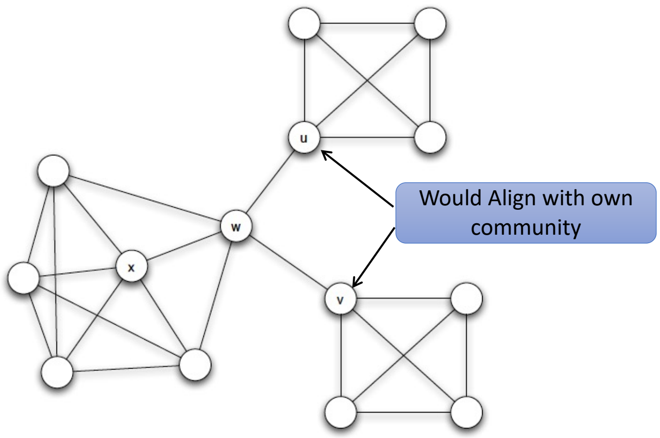
(a) *Two nodes are the initial adopters*

(b) *The process ends after three steps*

33

Diffusion and strength of weak ties

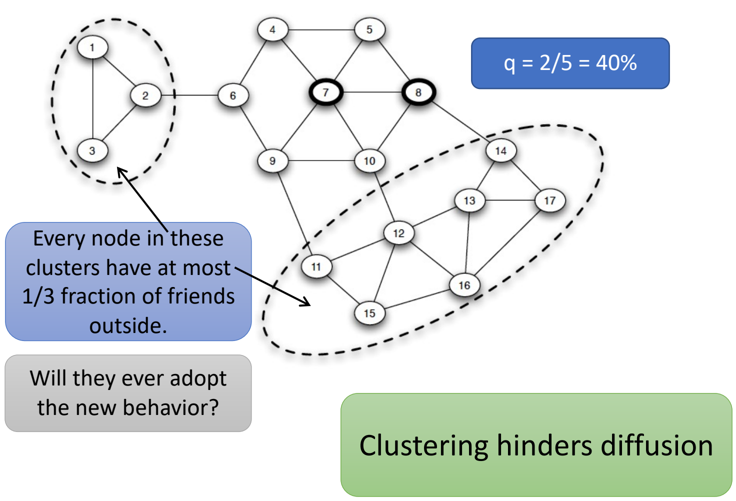
- Weak ties are conveyors of information
- But cannot “force” adoption of behavior



34

Diffusion and clustering

- Does clustering help or hinder diffusion?



35

What are the factors for a widespread diffusion?

- Initial adopters
- Network structure
- Threshold value q
  - Quality of product– payoff parameters a and b
- Example: viral marketing

36

More general models

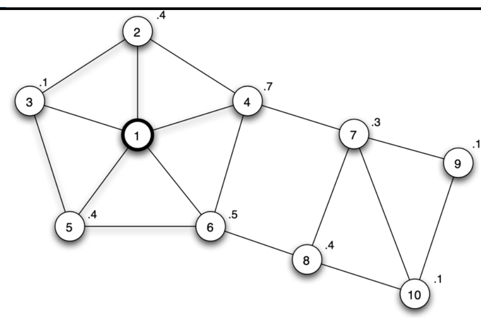
38

Cascades with heterogeneous thresholds

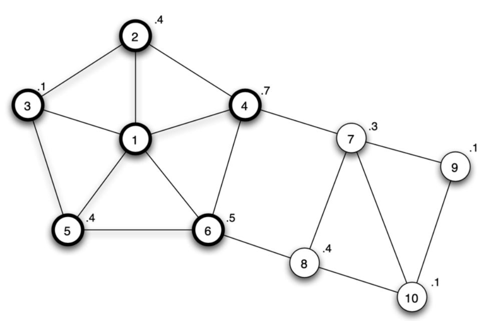
		w: A	w: B
v	A	a_v, a_w	$0, 0$
	B	$0, 0$	b_v, b_w

- Node v's threshold = $b_v/(a_v + b_v)$
  - Same calculation as before

39



(a) *One node is the initial adopter*



(b) *The process ends after four steps*

40

Further extension: linear threshold model

All friendships are not the same!
=> influence

Reference: Handout (on Canvas)

41

Influence maximization problem

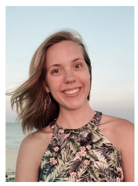
Given $k > 0$, select a set of k initial adopters so that the spread of the *new behavior* is maximized

42

Cascades and Overexposure in Social Networks: The Budgeted Case

Mohammad T. Irfan

Kim Hancock



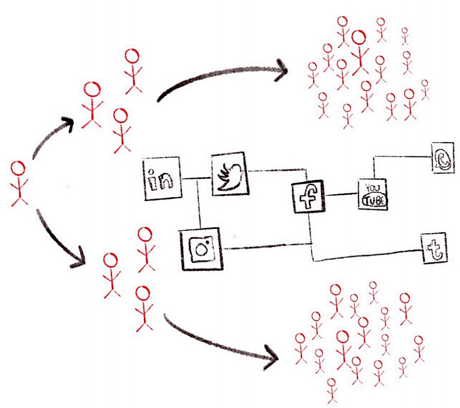
Laura M. Friel

AAMAS 2022
MAY 9 - 13 AUCKLAND, NZ

Paper Link

43

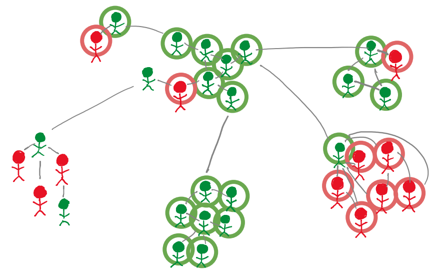
Cascades and influence maximization (IM)



44

Overexposure

Green: accepting node
Red: rejecting node



45

How do we select a set of initial adopters (or seeds) that will maximize the spread of influence while minimizing overexposure?

48

Unbudgeted seeding

Abebe, Adamic, and Kleinberg (**AAK**), AAAI 2018

- Polynomial-time algorithm for the unbudgeted case
- Proved hardness of the budgeted case

49

How do we select up to *k* initial adopters that will maximize the spread of influence while minimizing overexposure?

Paper Link

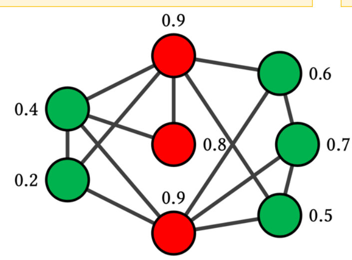
50

Modeling overexposure (AAK)

- Undirected, unweighted graph
- Each node: a criticality parameter, θ_i
- Product appeal, ϕ

Accepting node: $\phi \geq \theta_i$
Rejecting node: $\phi < \theta_i$

Product appeal = 0.7



51

Propagation model (AAK)

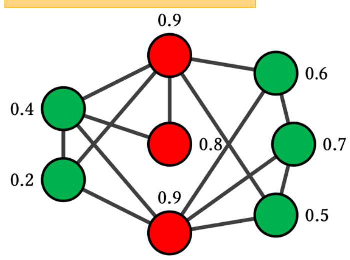
Accepting node: Sends information to ALL neighbors.	Rejecting node: Does not send to anybody. *Inflicts global cost!*

52

Overexposure problem

Given budget *k*,
maximize **payoff** = # of accepting – # of rejecting nodes reached

Example (budget, *k* = 1)



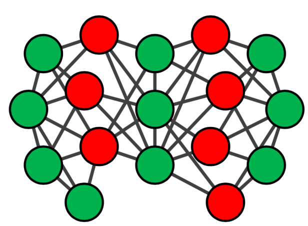
Select left: payoff = 2 – 3 = -1

Select right: payoff = 3 – 2 = 1

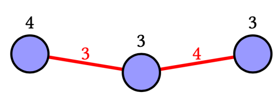
53

Cluster graph formulation

Assumption: A rejecting node cannot be at the boundary of more than two clusters of accepting nodes.



Input graph

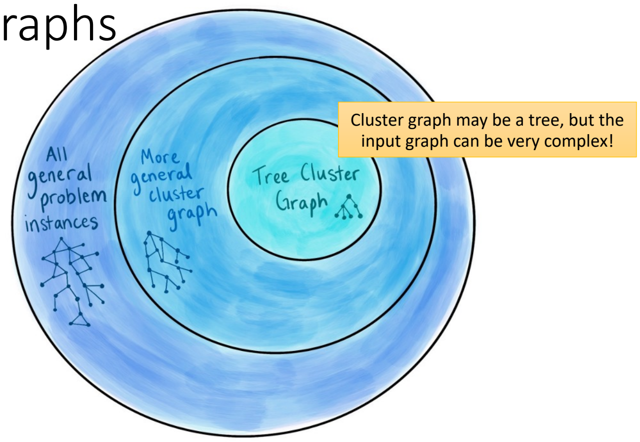


Cluster graph

Simple cluster graph for very complex input graph

54

Algorithms for classes of cluster graphs



55

Lower quality products need smarter algorithms to avoid overexposure.

Higher quality products can be coupled with extremely simple and fast greedy algorithms.

56