Network Science

Course Outline

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February 23, 2020

Summary

List of Class Students

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Each student please provide:

- Name
- Program

Brief Introductions

Brief Introductions

Each student please stand up and briefly introduce yourself

Course Web Site

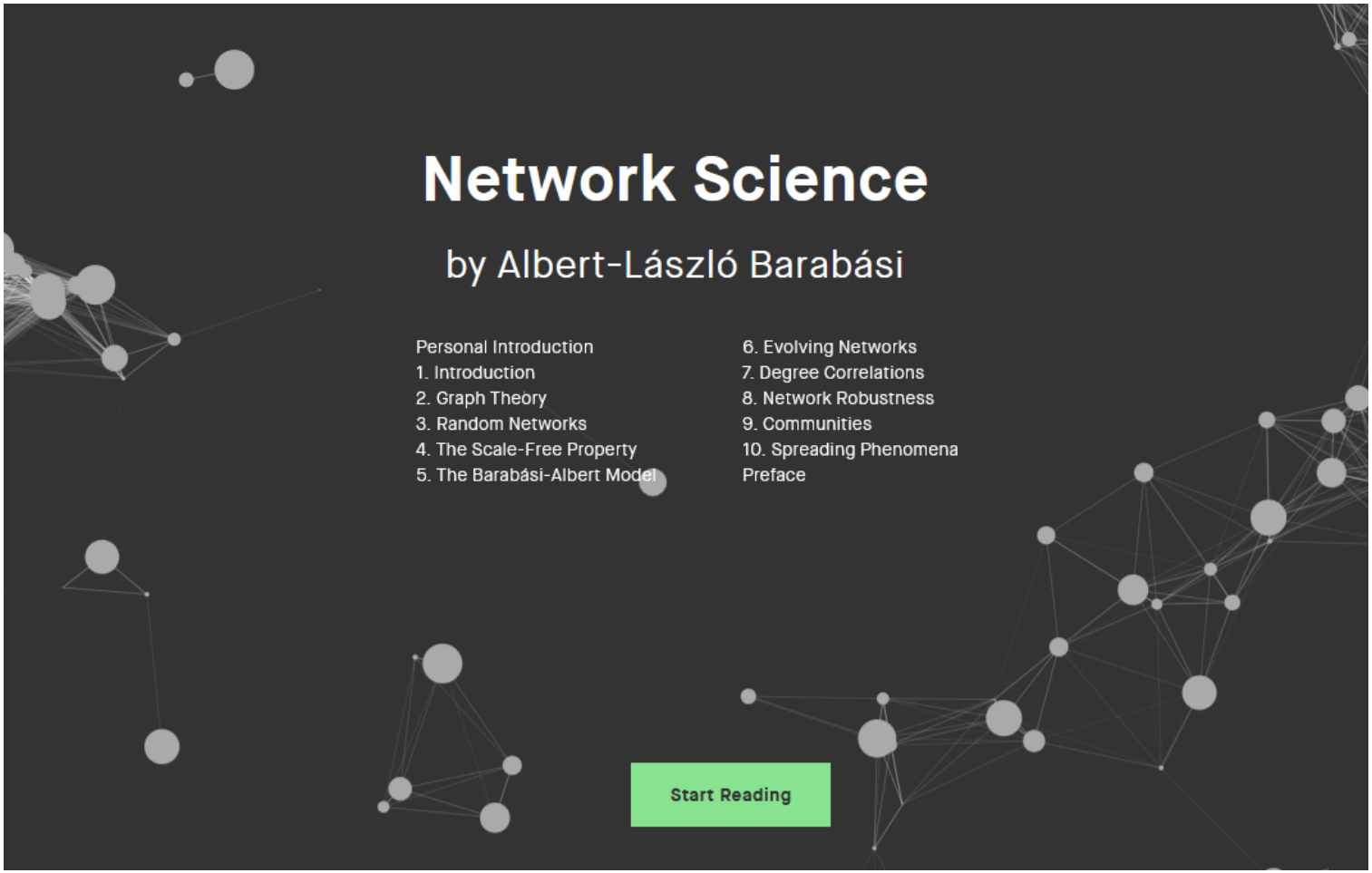
Course Web Site

http://www.ic.unicamp.br/~meidanis/courses/mo412/2020s1/

Book

Book

Network Science, by Albert-László Barabási
Cambridge University Press, 2016
`https://networksciencebook.com/`

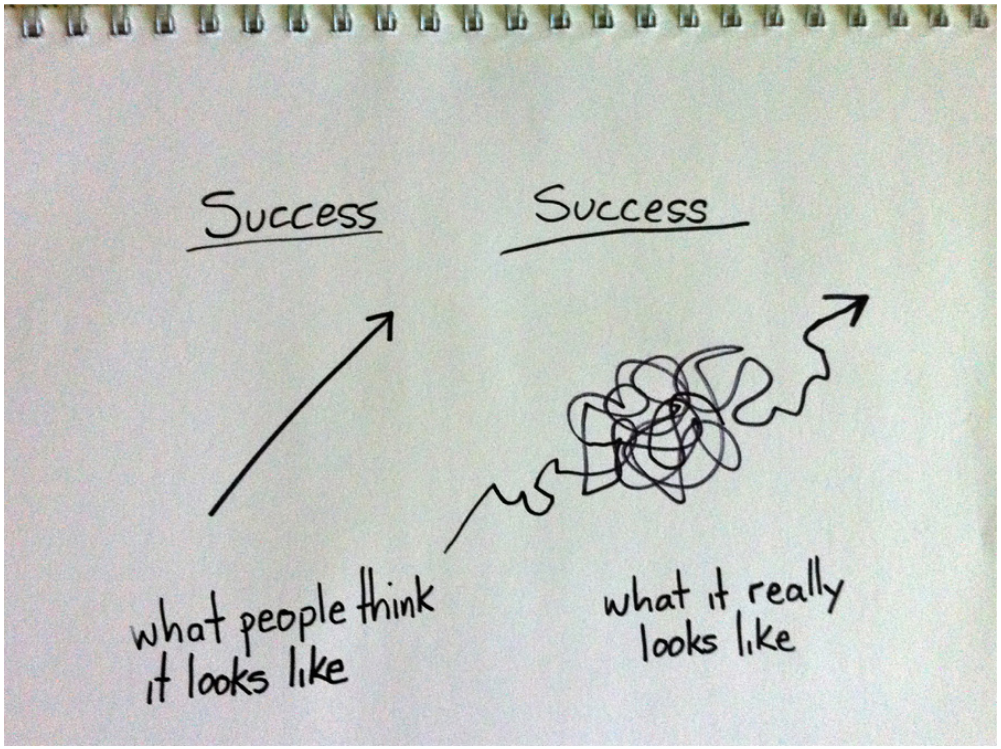


Book Author's Personal Introduction

Today and Paths to Success

Network Science today (after 15 years):

- dozens of conferences, workshops, schools per year
- $>$ 100 books, 3 journals
- most universities offer courses; one can get a PhD in 3 continents
- USD hundreds of millions for research



SUCCESS 1: Invasion Percolation and Prim's Algorithm

- Percolation: liquid flowing through a porous material
- Prim's algorithm: grow a minimum spanning tree using the smallest edge going out of the current component
- **Nature paper**

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FAIL 1: Second Network Paper

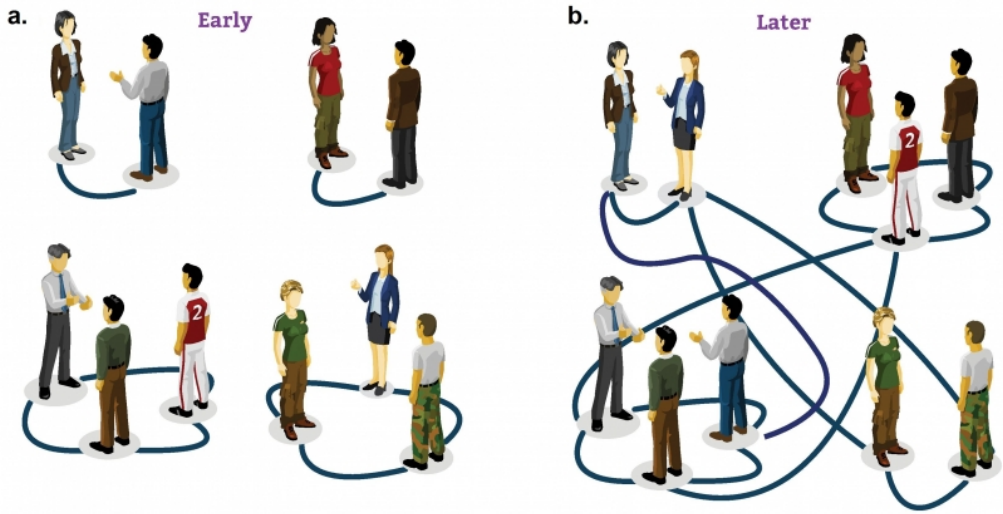
- Puzzled about networks (e.g, cables in a city)
- *Random graphs*, by Bollobás
- *The Origins of Order*, by Kauffman
- Second paper inspired by these books:
  - *Dynamics of Random Networks: Connectivity and First Order Phase Transitions*
- Rejected by four journals (1995-1997)
  - *Science*
  - *Nature*
  - *Physical Review Letters*
  - *Europhysics Letters*

FAIL 2: Mapping the WWW (or trying to . . .)

- Leave random graphs aside
- Look at real networks
- Letter to robot researchers asking about WWW degrees
- **No answers**
- Safer research: quantum dots
  - Two grants in 1997
  - Several students and a pos-doc
- Asimov's *Foundation* inspired network comeback
- 1998: asked his best student to join — she agreed!
- Reka Albert joined his group (of two people now)

FAIL 3: Small Worlds

- Two communities studying networks:
- Social scientists, the *six degree of separation* idea
- Mathematicians, with random graphs
- Watts and Strogatz 1998 paper on small world networks:
  - *Collective dynamics of 'small-world' networks*
- Compare to FAIL 1 Title:
  - *Dynamics of Random Networks: ...*
- Communicating your results



SUCCESS 2: Mapping the Web

- Hawoong Jeong joined the group (three people now)
- Built a WWW crawler
- Degree distribution determined
- Shock: not a Poisson distribution, but a power law
- **WWW is not a random network!**
- *Nature* paper: "six degrees" is "19 degrees" in WWW

SUCCESS 3: Reason for Power Laws (The Discovery)

- Random network:
  - each node chooses neighbors randomly
- WWW:
  - new pages tend to link to pages that already have many links
- This is **preferential attachment**
- Simulations showed that growth by preferential attachment lead to networks whose degree distribution follows a **power law**
- These are the **scale-free** networks
- They also have **hubs**:
  - nodes with degree much higher than average
- Many real life networks fit this pattern: actors, computer chip wiring, power grid, ...

SUCCESS 4: Three papers in seven days (The Rush)

- *Nature*: The WWW is a scale-free network (19 degrees of separation)
- *Science*: Many other networks are scale-free, and preferential attachment is an explanation
- *Physica A*: Longer version

- Had to call the editor of *Science* to overturn a reject without review decision, and succeeded!

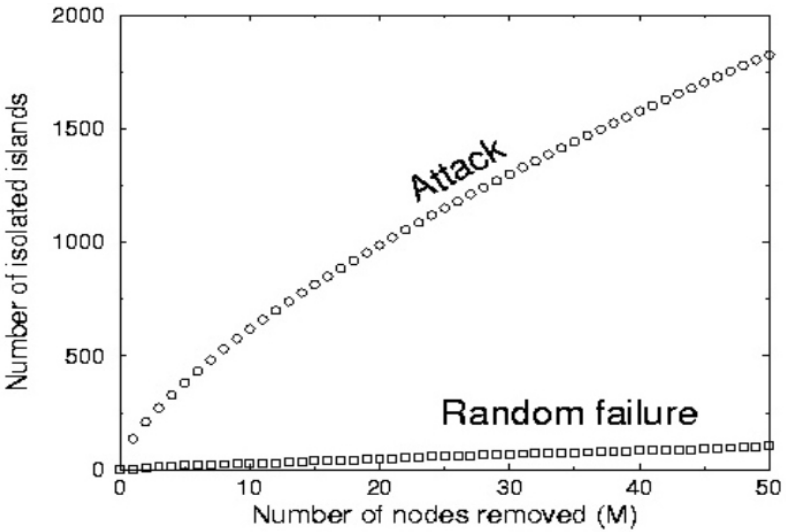
Quitting Materials Science

- Research group: 4 student and 1 pos-doc
- All but Reka working on surfaces and quantum dots
- Called a meeting
- No more materials science
- 100% networks from now on
- Two students left
- The rest joined the new field

FAIL 4: Funding (1999)

- Got new grant for materials science
- Had to return it: no more interest
- Submitted a proposal do DARPA
- Scale-free networks resistant to random failures, but . . .
- . . . shockingly sensitive to attacks
- Also wrote paper on that
- *Science* rejected paper
- DARPA rejected proposal

SUCCESS 5: Failure *versus* Attack



- Failure $\times$ attack paper submitted to *Nature*
- Accepted!

FAIL 5: Nemesis

- Journey was not without its enemies
- John Doyle, from Caltech
- Small world property easier to explain
- Scale-free property required more work
- Proof only came in 2001 (Bollobás, Riordan, Spencer)
- Community started to appreciate central role of degree distribution

Personal Introduction Summary

- Highly cited papers, funding, journals
- Path not straight
- Collaboration was key ingredient
- Multidisciplinarity