Emerging of scale-free network due to scientific cooperation

Science as an example of critical behaviour in complex network

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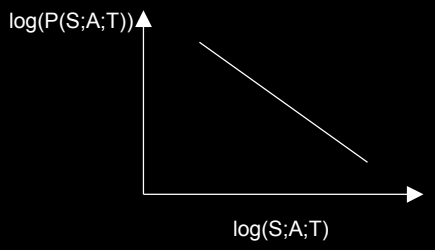
Self-organized criticality

- Square grid of boxes
- At each time step a particle is dropped into a randomly selected box.
- When a box accumulates four particles, the particles are redistributed to the four neighbouring boxes, or in the case of edge boxes, lost from the grid.
- Redistributions can lead to further instabilities, with avalanches of particles lost from the edge of the grid.

Self-organized criticality

Power law distributions for

- Avalanche size
- Avalanche area
- Duration of given avalanche



SOC - examples

- Earthquakes
- Forest fires
- Landslides
- Epidemics
- Wars
- Stock-market crashes

Inspiration

- Scientists are the agents which try to invent some new ideas. They read the papers of other researchers and basing on read ideas they build their own new ideas.
- They usually read the papers of people whose position in some domain of science is meaningful.

Inspiration

- If their amount (level, quality) of ideas is sufficient they publish a paper.
- After publishing the scientist has to collect some new ideas to create further new papers.

Model

- Network of N nodes

meaning

node = scientist

Model

- Directed links

meaning

link $i \rightarrow j$ = scientist *i* has an impact on scientist *j.* Scientist *j* takes an inspiration from work of scientist *i.*

Model

- Each node has assigned two hidden variables: $0 \leq c_i(t) \leq 1$ and *time(i)*

meaning

$c_i(t)$ – potential to publish a paper

time(i) – time from scientist's last publication – measure of attraction of scientist. The longer someone has no publications the less interesting for others he/she is.

Model – evolution rules

$$c_i(t+1) = c_i(t) + \sum_{j=1}^{k_{in_i}} \alpha \cdot e^{-time[j]/\tau}$$

$$if \quad c_i(t) > 1 \quad then \quad c_i(t) = rand(1) \quad and \quad time(i) = 0$$

meaning

In each step the scientist *i* draws inspiration from ideas of other people whose papers he has read. The older paper is – the less inspiriations can provide for scientist *i*.

α - strength of influence

τ- how fast a paper becomes stale

If c_i crosses critical value equal to 1 then scientist wrotes a publication and his resources of ideas are decreased.

Model – evolution rules

- After each time step all network is rewired with preferential attachment:

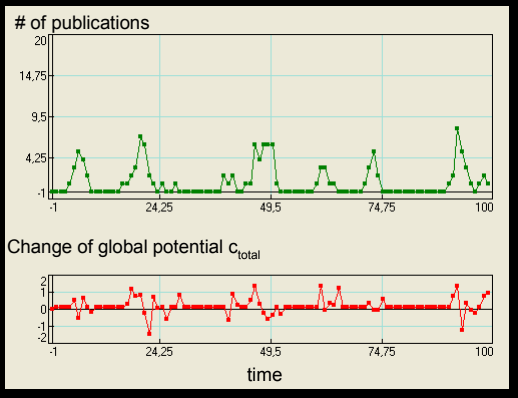
$$\Pi_{i\to j} = \frac{t_i^{-1}}{\sum_s t_s^{-1}}$$

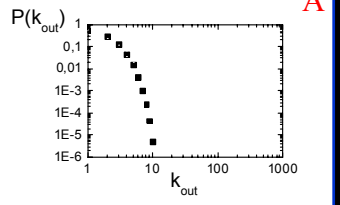
meaning

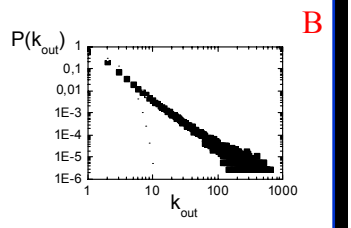
Each scientist tries to observe the most interesting publishers.

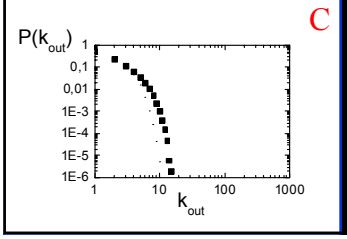
Remark: rewiring of all links in the network is not realistic, but makes the results more legible. One can assume only partial rewiring which means that all links will be rewired after larger number of time steps.

Model - simulations

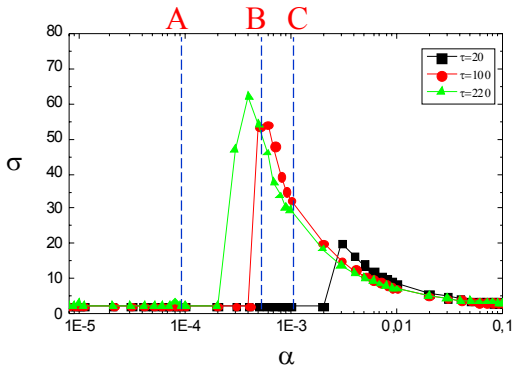






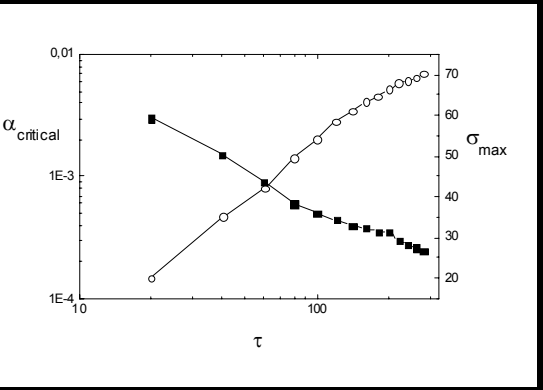


Results



Variance of out degree distribution as a function of influence strength

Results



Futher investigations

- Check distributions of avalanches
- Observe how an only partial rewiring affects results
- Observe how a new domain of science is created thanks to very influential scientist