11. KOMPLEKSSÜSTEEMID

1. General ideas

OF INITIAL IDEAS

simple is that which consists of one thing or element
complex is what is composed of more than one or many parts

Chambers, 1961

"The question is," said Alice, "whether you can make words mean different things."

L. Carrol, 1871

"Dissection is one of the most highly developed skills in contemporary western civilization: the split-up problems into their smallest possible components. We are good at it. So good, we often forget to put the pieces back together again."

A. Toffler, 1984

simplicity ↔ complexity

Chambers Dictionary

simple – consists of one thing or element

complex – composed of more than one or many parts

- is simple sometimes just simplified?
- what is the difference between
  - simple and simple?
  - complex and complex?
- how simple is simplicity?
- how complex is complexity?

Of simplicity

simple rules
proportionality
causality

Hooke's law
Ohm's law
Fourier's law
…….

Questions:

(i) is simple sometimes just simplified?

(ii) what is the difference between simple and simple?

Deepness:

"the simplicity of Fourier's mathematical description of heat propagation stands in sharp contrast to the complexity of matter considered from the molecular point of view."

Of complexity

com = together

plectere = to plait

_____

complexity

There is nothing more simple than what was discovered yesterday but there is nothing more complicated than what will be discovered tomorrow.

parts → subparts → subsub …
hierarchy

↑

A complex system is composed of parts

interrelated in a way which is hard to understand.

↓ ↓

interactions model
scaling prediction

conclusion:

different structure is observed at different

depth in the hierarchical description

To understand complexity:

multiple viewpoint:

real space + phase space

system theory + computation

mathematical ”anatomy” in a high – dimensional phase space

low – dimensional phase space → geometrical methods

high – dimensional phase space → generalize

naturalists’ viewpoint

make a collection of complex behaviours

list them up

classify them

Of creating complexity

- building hierarchies
- using recursive algorithms
- using coupling between structural elements
- taking into account memory effects

  ……

Nonlinearity – essential property
of complex systems

"Linearity means that the rule that determines what a piece of a system is going to do next is not influenced by what it is doing now."

M. Feigenbaum, 1992

Nonlocality – another property
of complex systems

Concluding remarks

"Common sense usually so good at distinguishing
between true and false
fails in situations in which …
logic no longer suffices"

H. Scheid, 1993

Characteristic of contemporary world:

"… the need to grasp a complex system
without reduction to an ensemble
of simple elements …"

Kaneko & Tsuda, 1994

if nonlinear elements are put together then

"the whole is bigger than its parts"

Aristoteles

2. Terviklus / complexity

1. T/C süsteemid koosnevad paljudest seostatud osadest, mis võivad interakteeruda
2. T/C süsteemides võib esineda kriitilisi olukordi, kus väikesed välistõuked võivad viia süsteemi tasakaalust välja ja uue oleku tekkele
3. T/C süsteemides võib esineda iseorganiseerumist, mis algab lokaalsetest muutustes kuid süsteemi uue oleku omadused on globaalse iseloomuga
4. T/C süsteemid on avatud ja adaptiivsed ning tihti määratud lihtsate reeglitega
5. Muutused T/C süsteemides tekivad kitsas parameetrite vahemikus, nn kaose piiril

   ... – kord – T/C – kaos – T/C – kord – ....
6. T/C süsteemid on mittelineaarsed

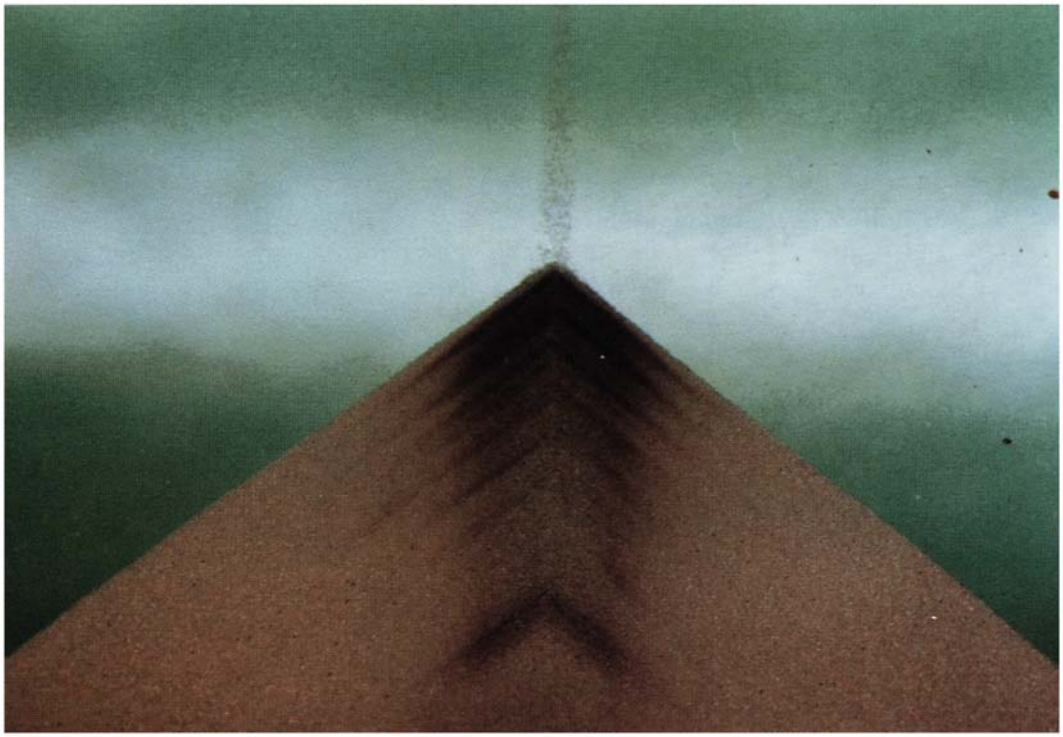
Lihtsate mudelite käitumine?

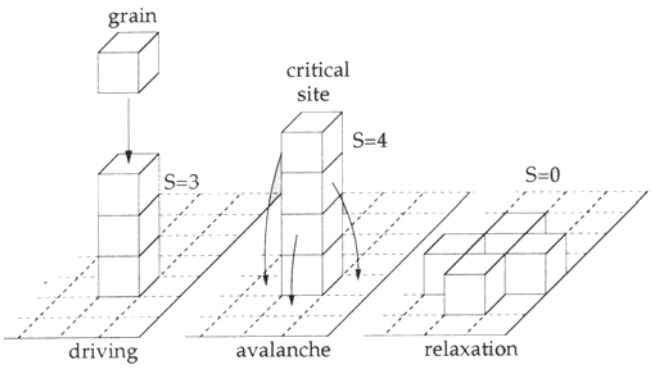
- universaalsus – ?
- ennustatavus – ?
- bifurkatsioonid – ?
- sümmeetria rikkumine – ?

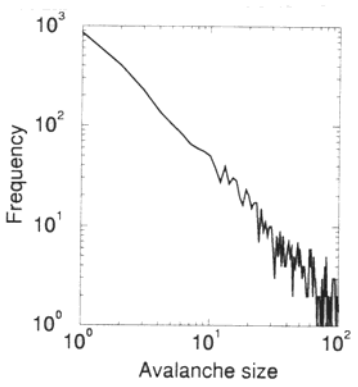
Lihtsaid mudeleid

- liivakuhik
- pendlite süsteem
- metsatulekahjud
- maavärinate blokkmudel
- maastike kujunemine

Liivakuhik, kuidas tekivad varingud?







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0	2	2	1	2

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2	3	2	3	0
1	2	4	3	2
3	1	3	2	1
0	2	2	1	2

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2	3	3	3	0
1	3	0	4	2
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3	2	1	0	2
0	2	3	2	2

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0	2	3	2	2

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0	2	3	2	2

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0	2	3	2	2

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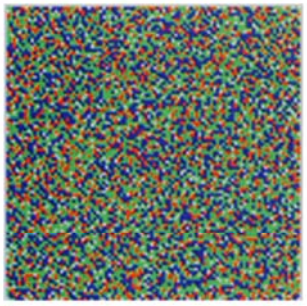

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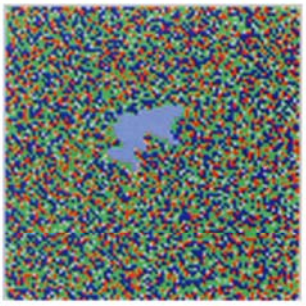

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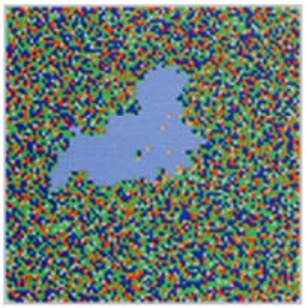
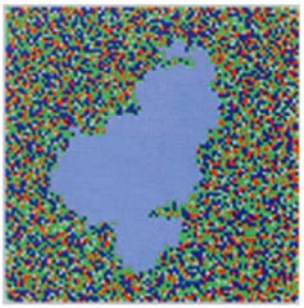
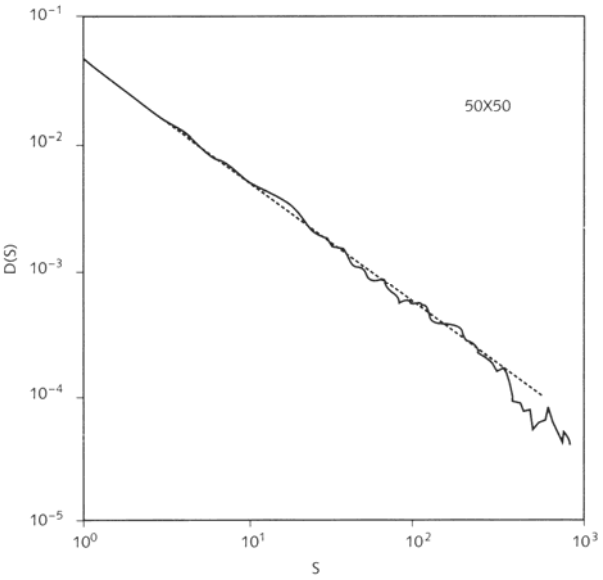


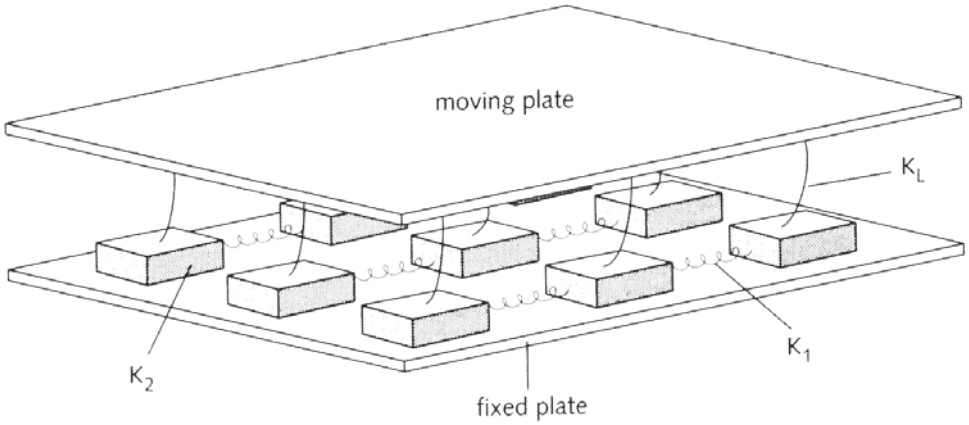
c

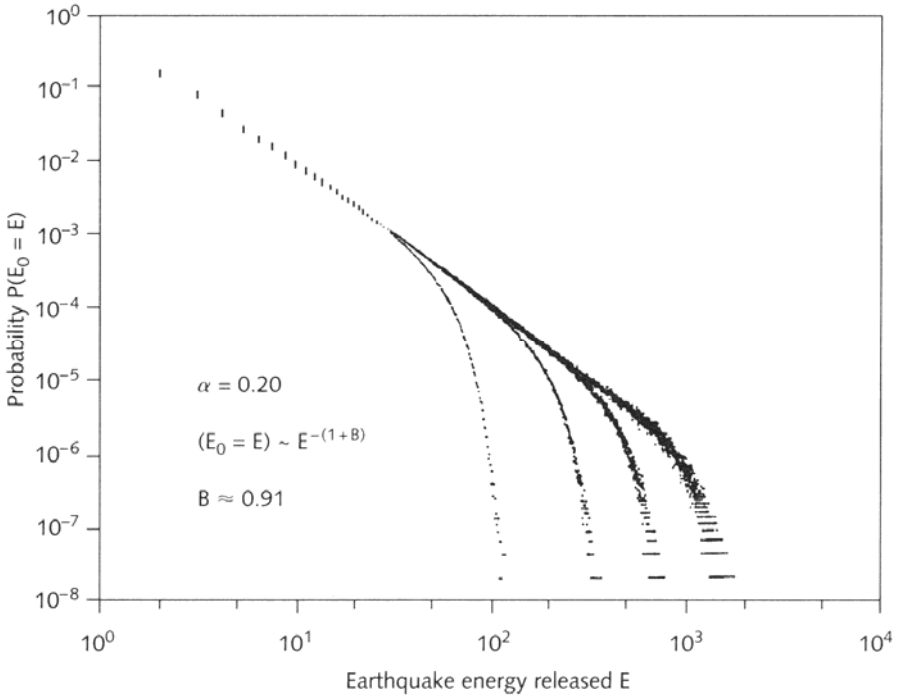


d

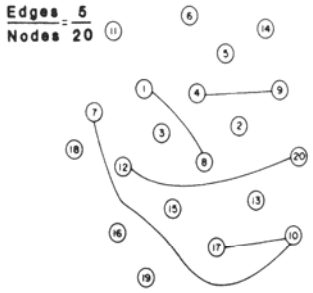


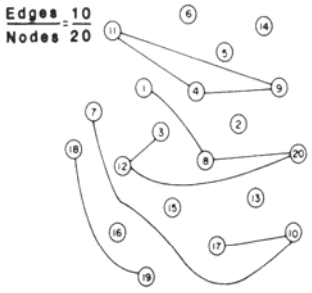
Maavärinate blokkmudel, Burridge-Knopoff

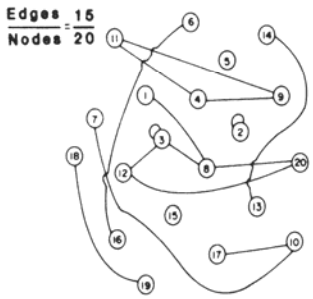


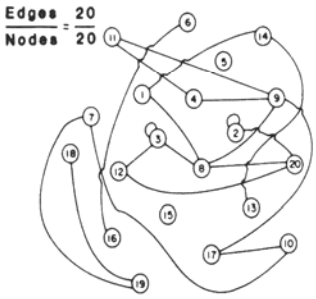


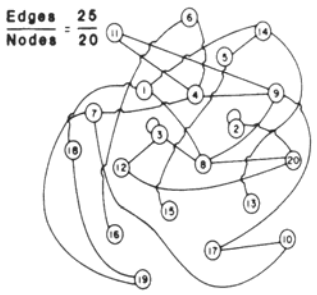
Võrgustikud, kujunemine

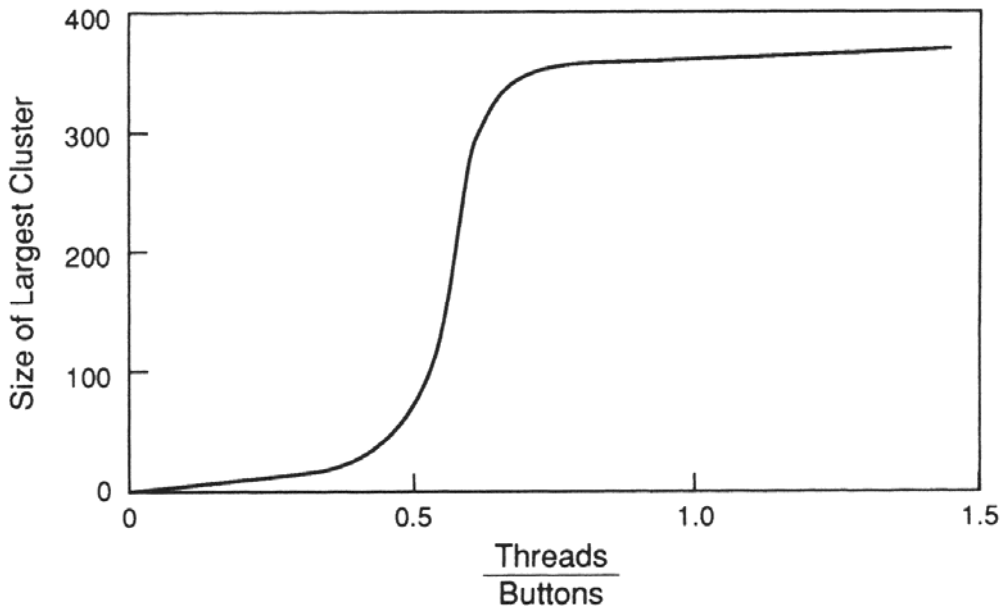




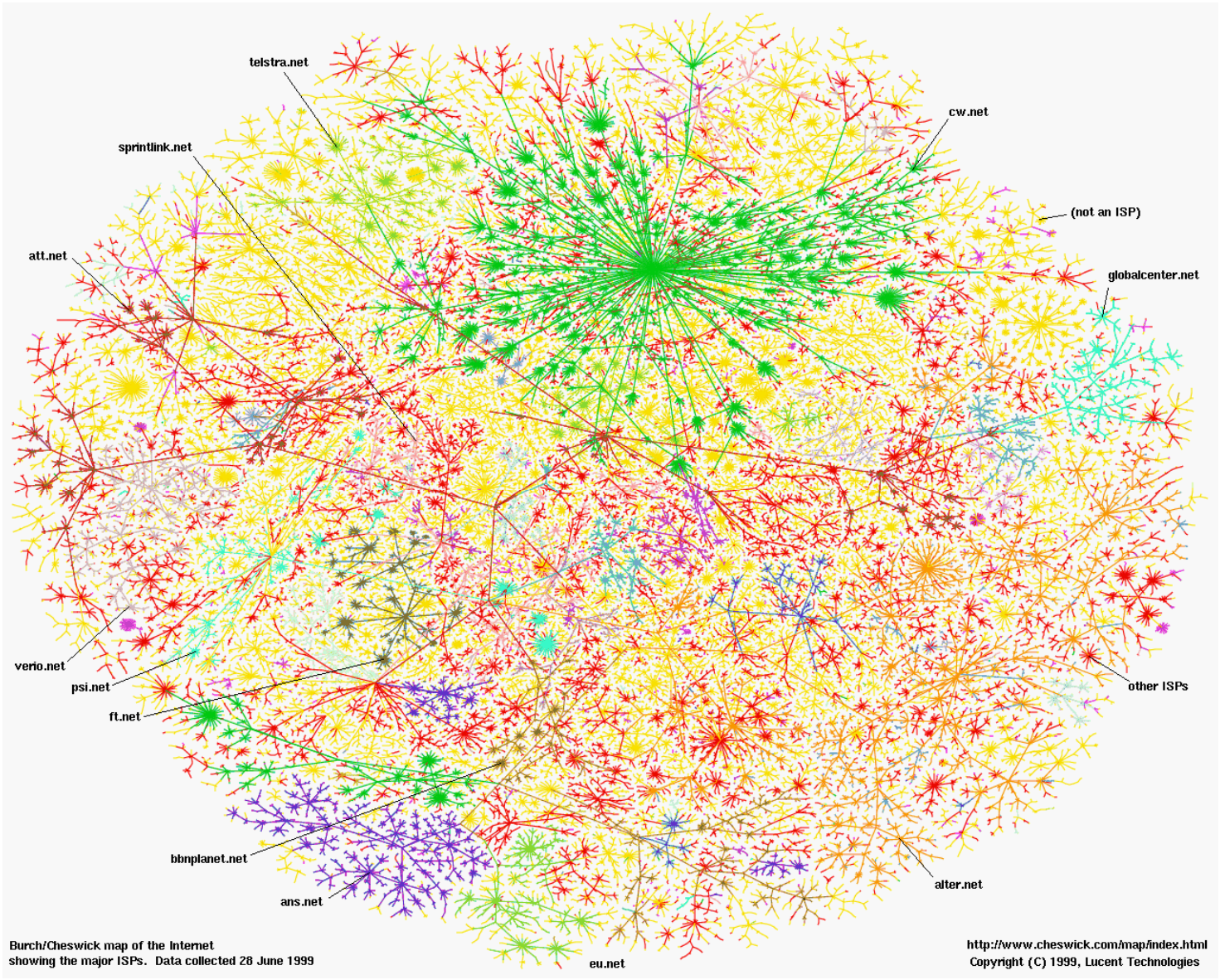








Internet, skeem



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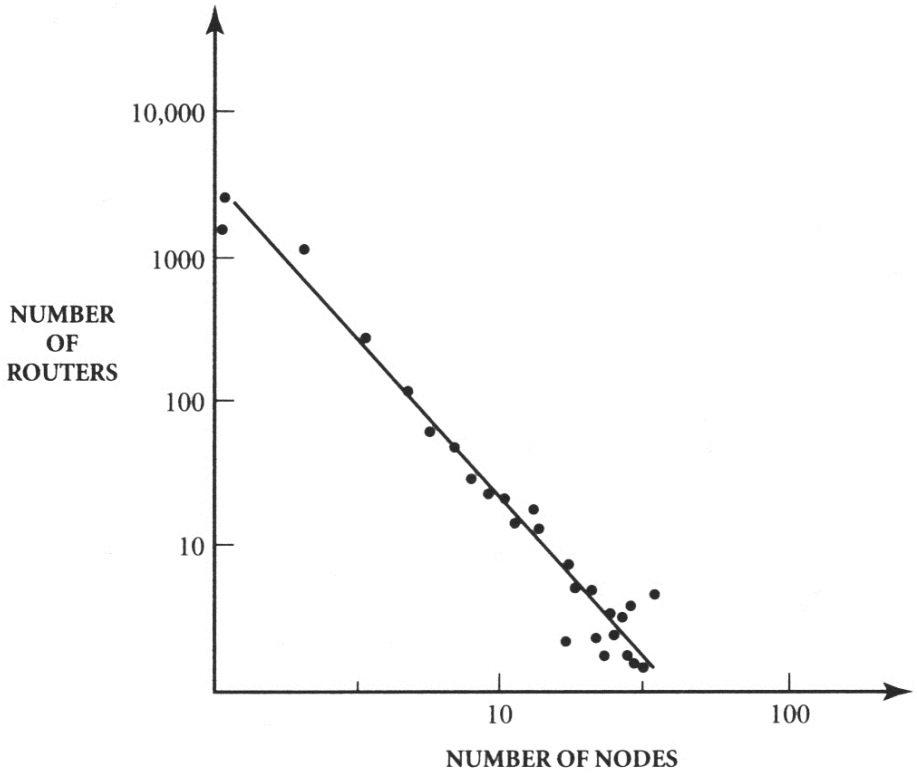


Nähtused

- dramaatilisted sündmused – varingud, katastroofid...
- fraktalid
- 1/f müra
- Zipf'i seadus

Sünkroonsus

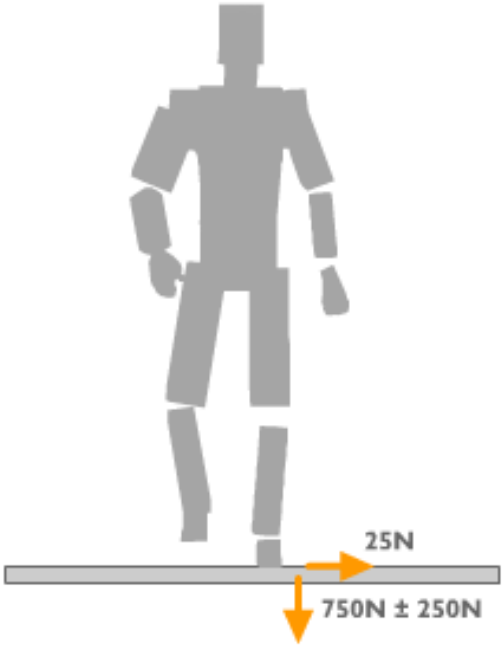
loodus:

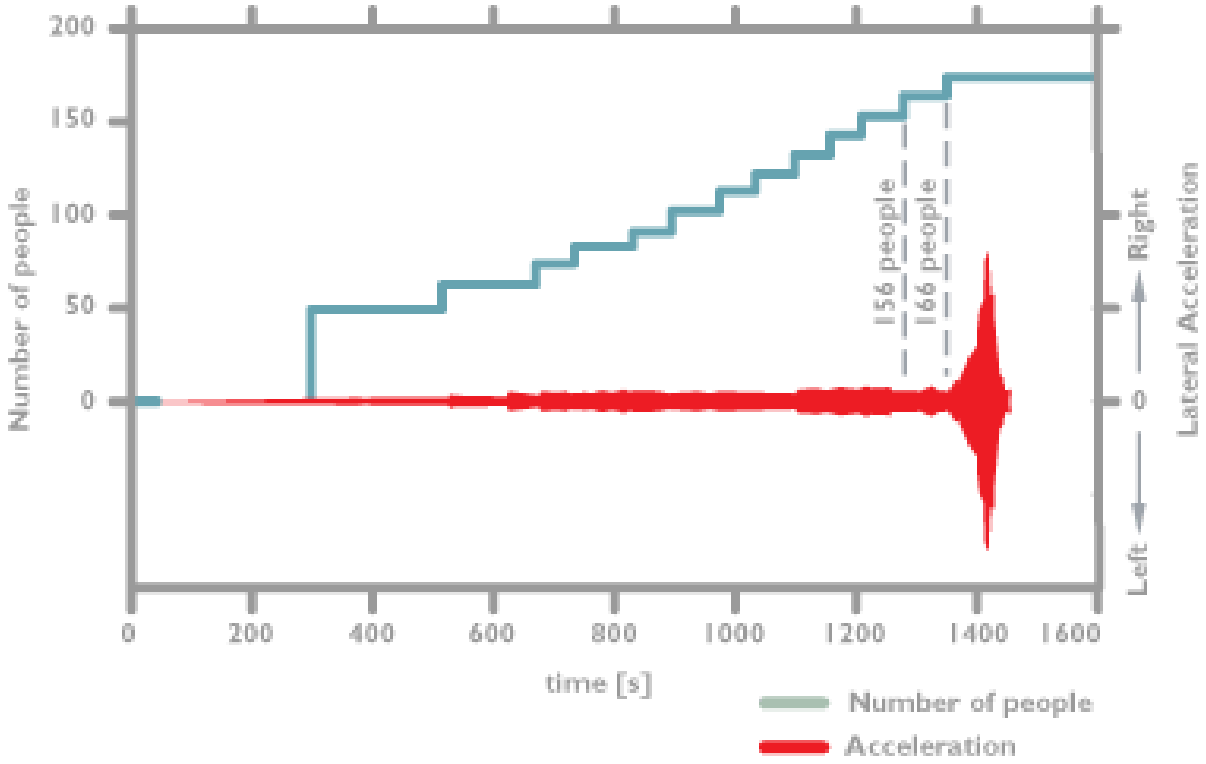
- jaanimardikad –fireflies
- südame sinuatriaalsõlm

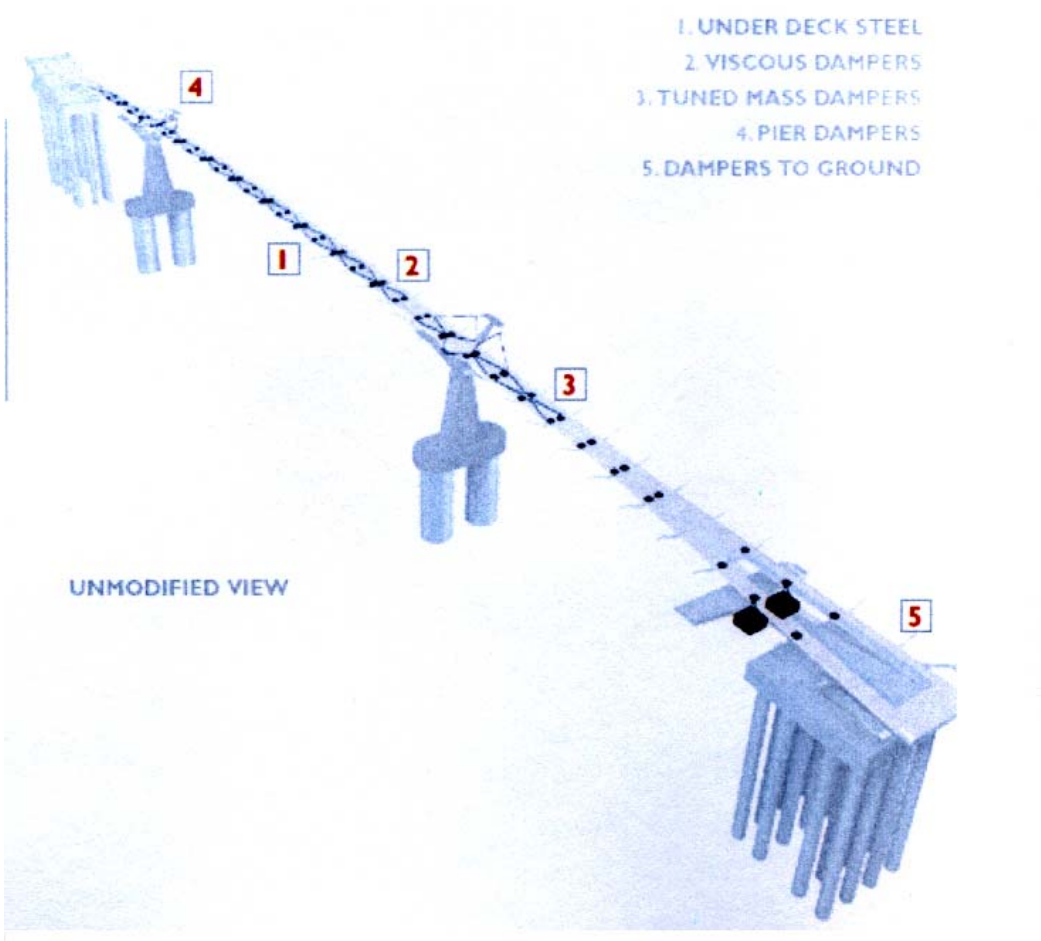
tehissüsteemid:

- Huygensi pendlid
- Josephsoni efektid
- Millenium Bridge Londonis

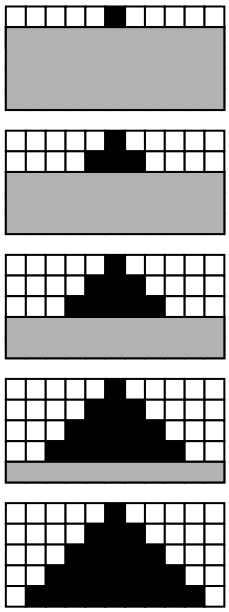
Sünkroonsus – Millenium Bridge, London

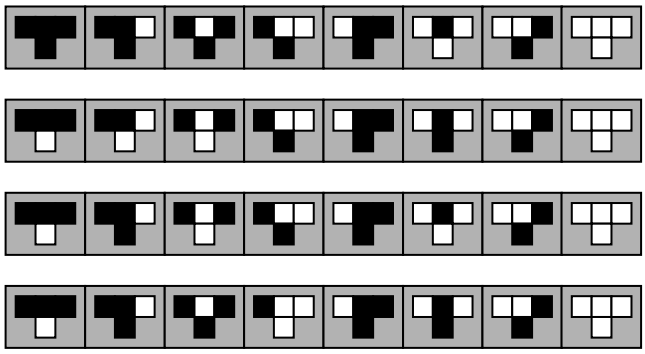


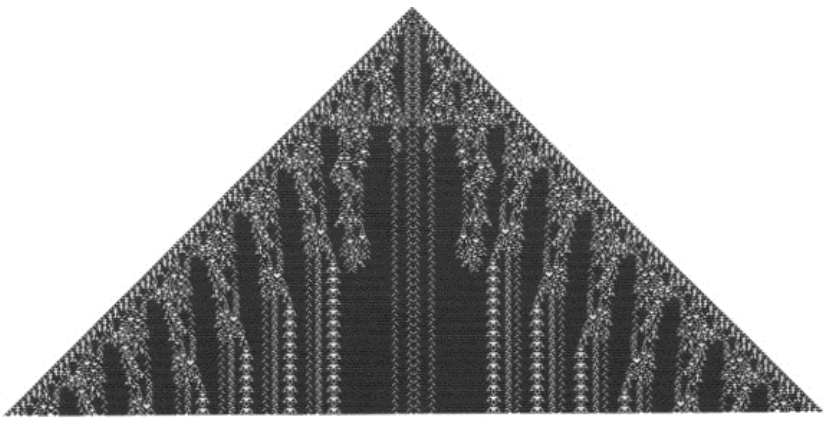

200
150
100
50
0
Number of people
156 people
166 people
Right
0
Left
Lateral Acceleration
0
200
400
600
800
1000
1200
1400
1600
time [s]
Number of people
Acceleration

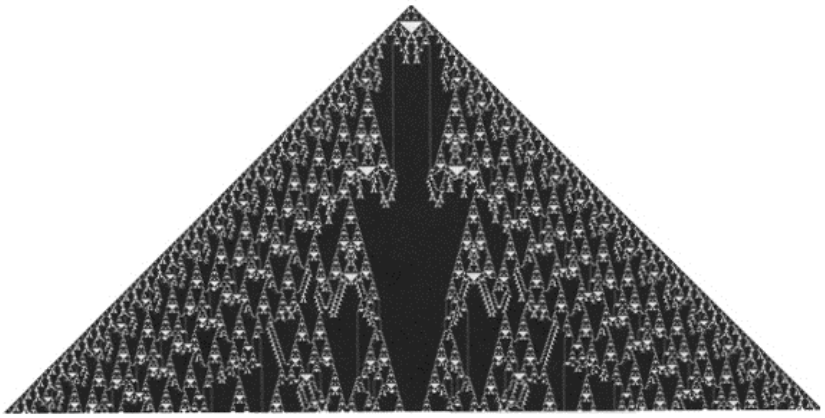

1. UNDER DECK STEEL
2. VISCOUS DAMPERS
3. TUNED MASS DAMPERS
4. PIER DAMPERS
5. DAMPERS TO GROUND
4
1
2
3
5
UNMODIFIED VIEW

Kas intuitsioon töötab? Rakuautomaadid





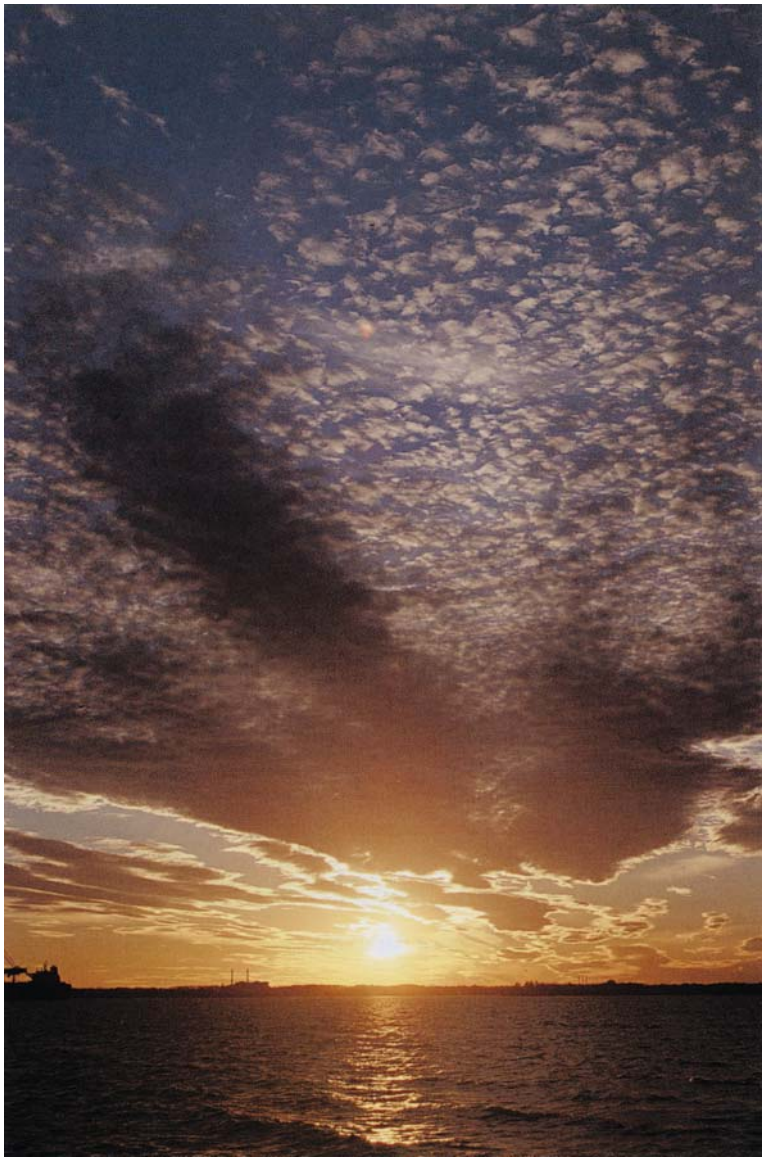




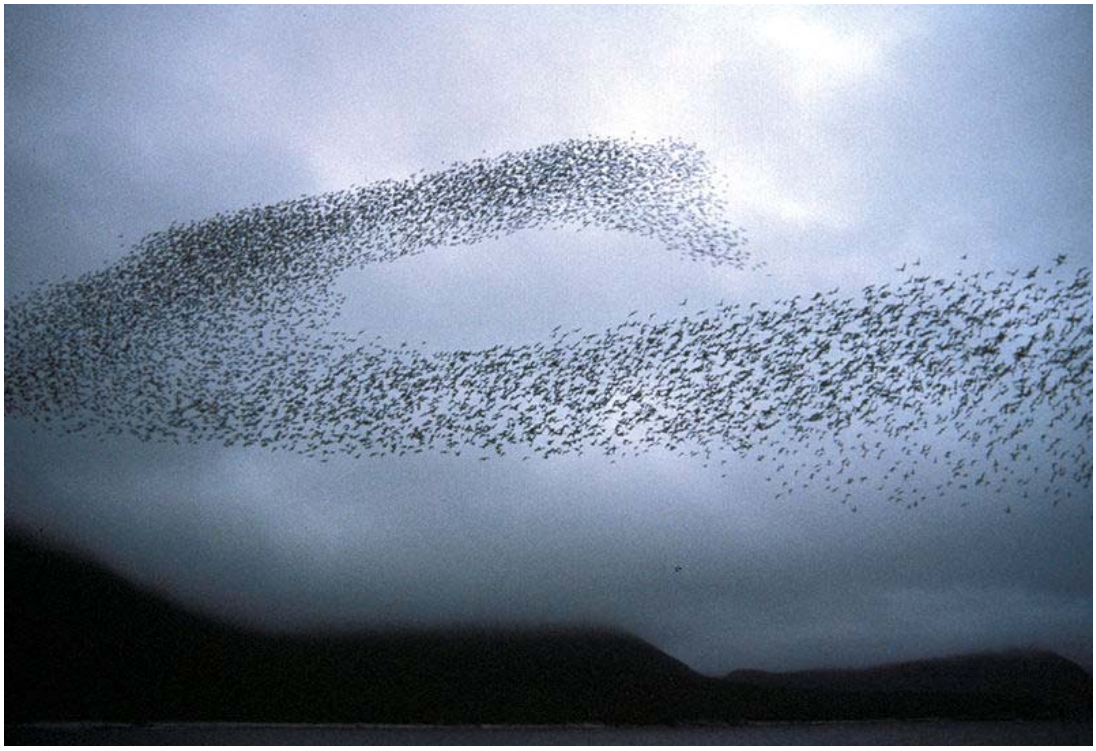
Mittelineaarsus

Lihtne seletus – puuduvad võrdelised seosed
ehk:
Aristoteles: summa on suurem kui üksikosad kokkuliidetuina
Hundertwasser: sirgjoon viib inimkonna mandumiseni....
Mandelbrot: pilved pole kerad, rannajooned pole kaared, puukoor pole sile...

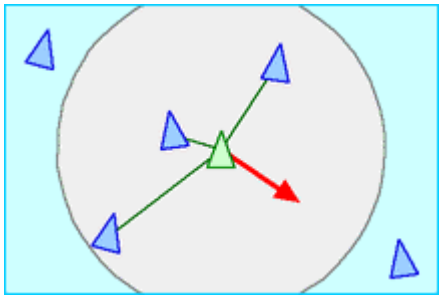
Oluline printsiip - **maailm on mittelineaarne ja lineaarsus on lähendus, mitte aga vastupidi**



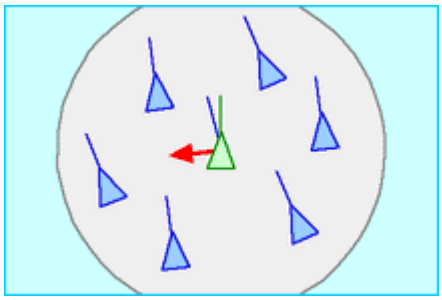
Boids – bird swarms



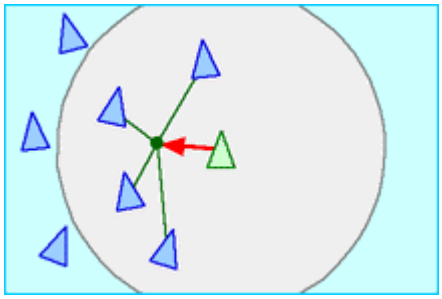
Boids – rules



Separation: steer to avoid crowding local flockmates

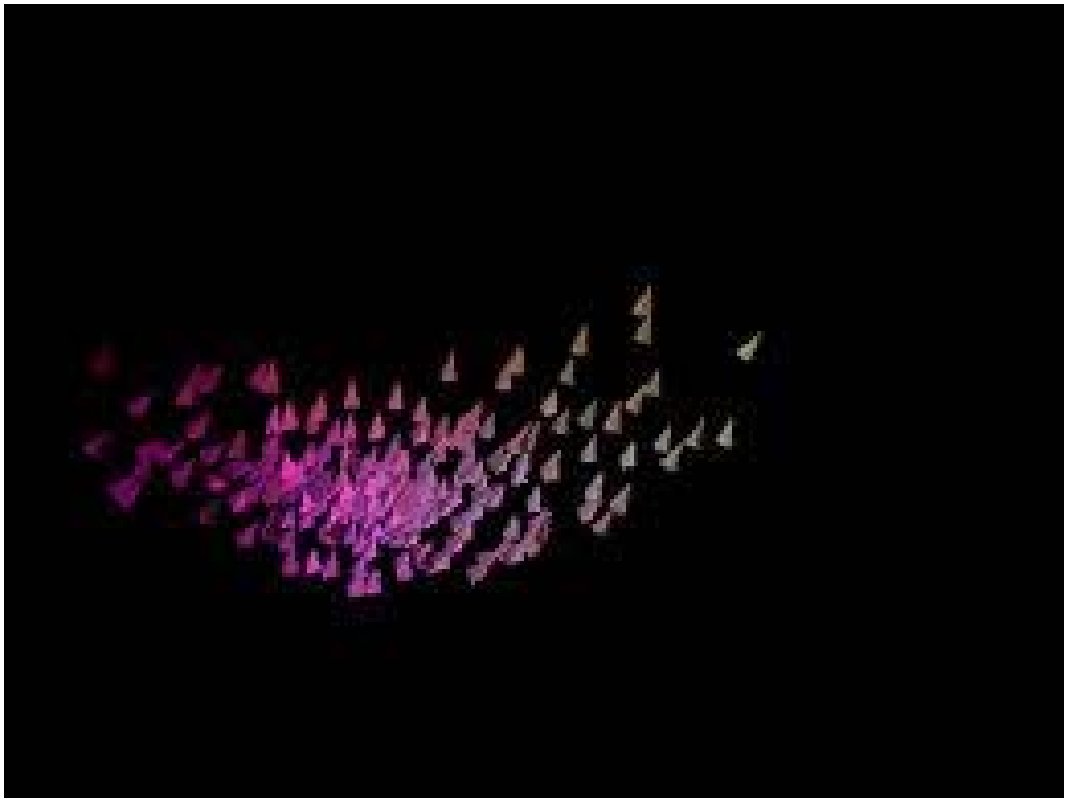


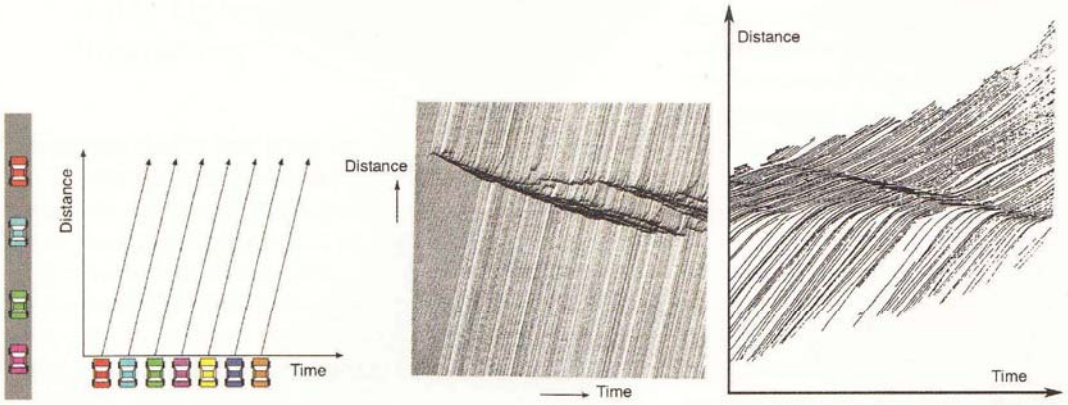
Alignment: steer towards the average heading of local flockmates



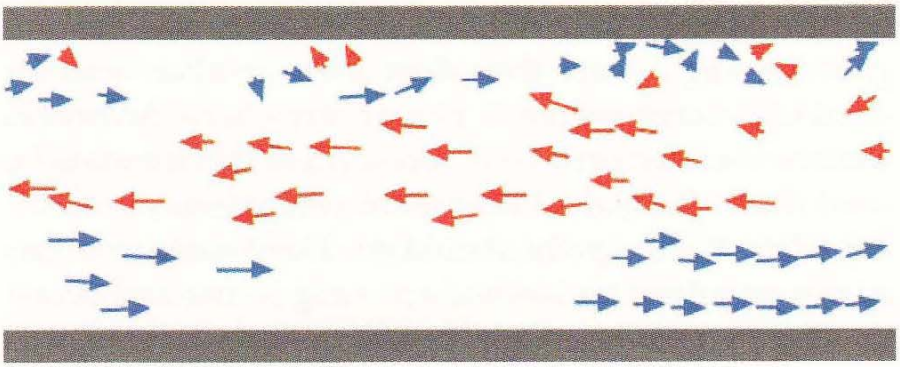
Cohesion: steer to move toward the average position of local flockmates

Boids – simulations

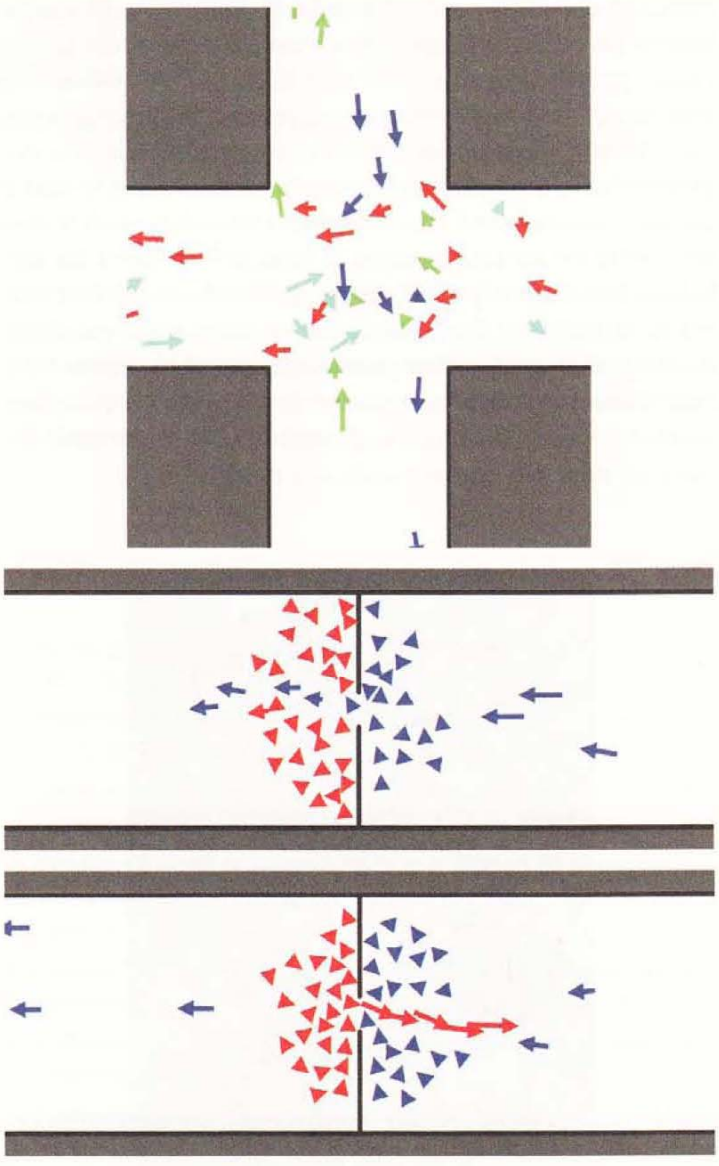




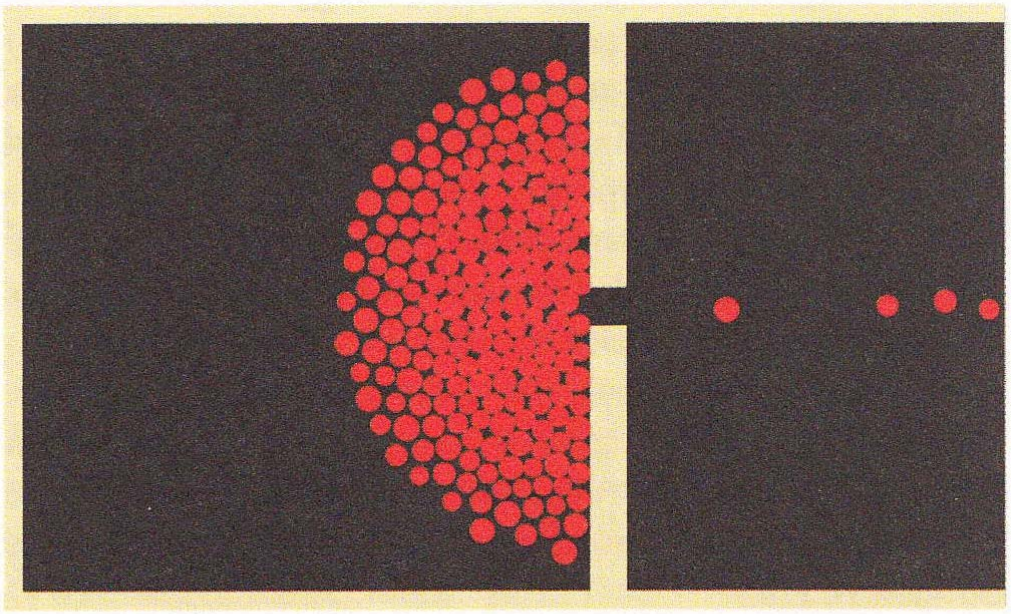
Phantom jams. In a computer model, cars move down a road at a steady speed if their progress is unimpeded (left). But if the traffic is sufficiently dense, a single small and transient disturbance can trigger jams (middle: jams are the dark bands) which move upstream against the direction of driving and develop complex forms, such as splitting into a series of knots of congestion. Jams like this are commonly seen in real traffic data (right). (Credits: (middle) from K. Nagel & M. Paczuski, *Phys. Rev. E* **51**, 2909 (1995); (right) from J. Treiterer et al., 'Investigations and Measurement of Traffic Dynamics', Appendix IV to the Final Report EES 202-2, Ohio State University, Columbus, 1965.)



Streams in a computer model of pedestrians in a corridor. (Credit: Courtesy of Dirk Helbing, ETH Zurich.)



Snapshots of model 'walkers' negotiating a crossroads (top) and a doorway (bottom, showing two snapshots where 'red' and 'blue' capture the doorway). (Credit: Courtesy of Dirk Helbing, ETH Zurich.)



A simulated crowd trying to exit rapidly from a room can get jammed in a 'panic state', in which individuals escape only slowly and sporadically. (Credit: Courtesy of Dirk Helbing, ETH Zurich.)

E.Estrada. The structure of Complex Networks

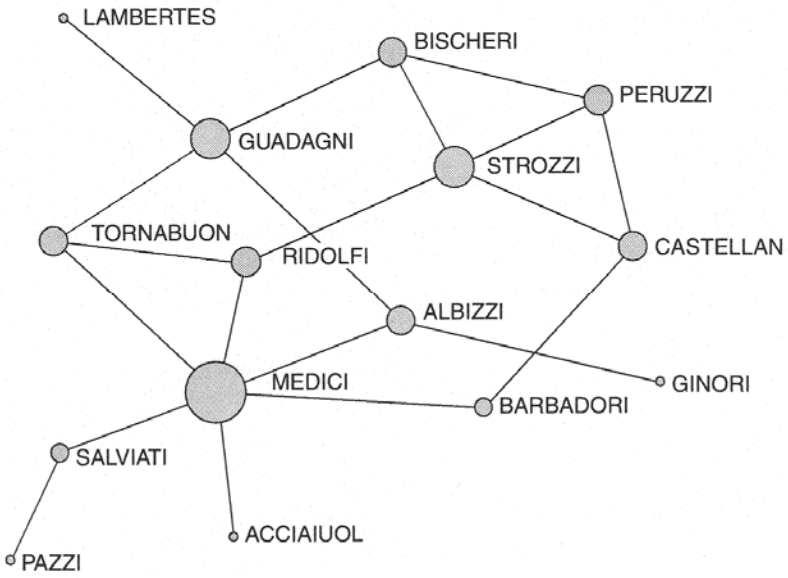


Fig. 1.13
Node degrees. Representation of the node degrees proportional to the radii of the circles of each node. The network illustrated corresponds to the marriage relations between pairs of Florentine families in fifteenth century (Breiger and Pattison, 1986).

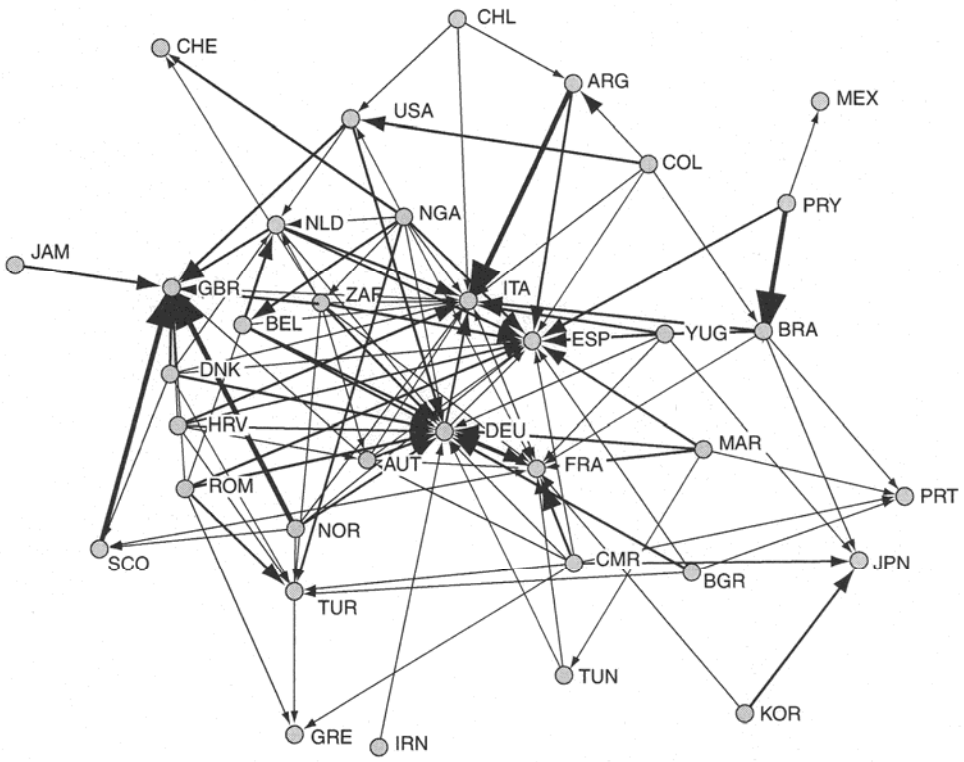


Fig. 1.5
Weighted directed network. Representation of the transfer of football players between countries after the 1998 World Cup in France. Links are drawn, with thickness proportional to the number of players transferred between two countries.

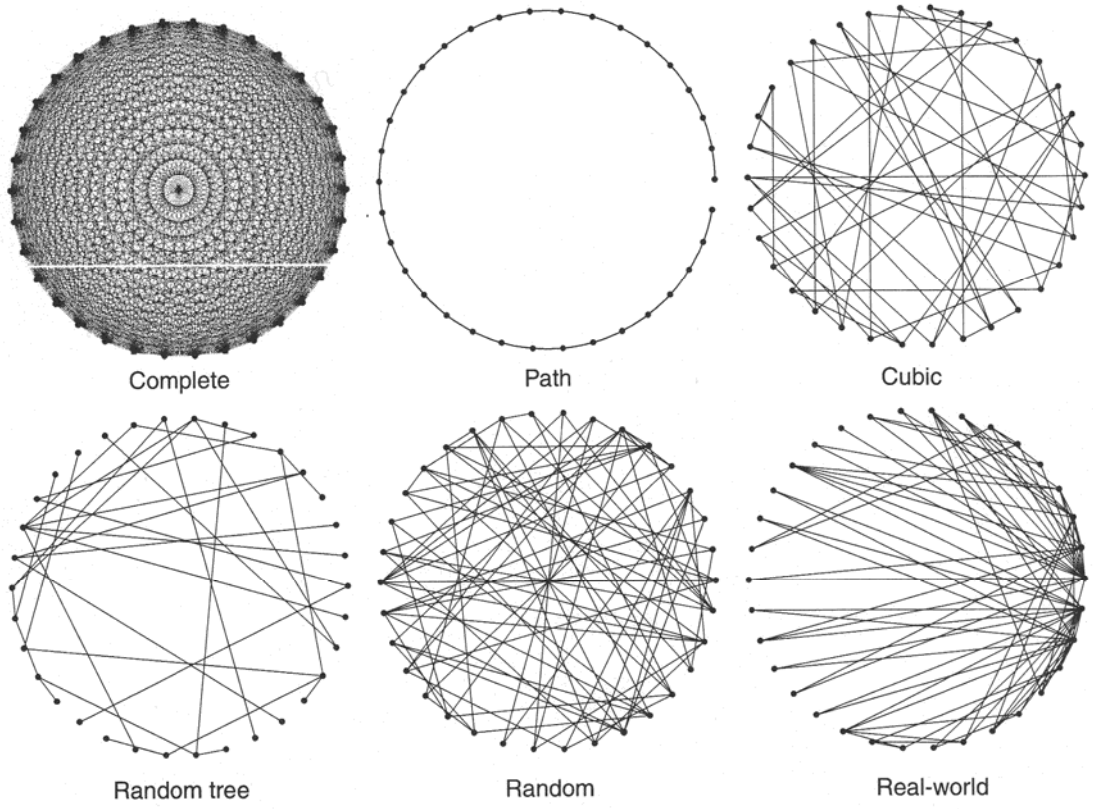
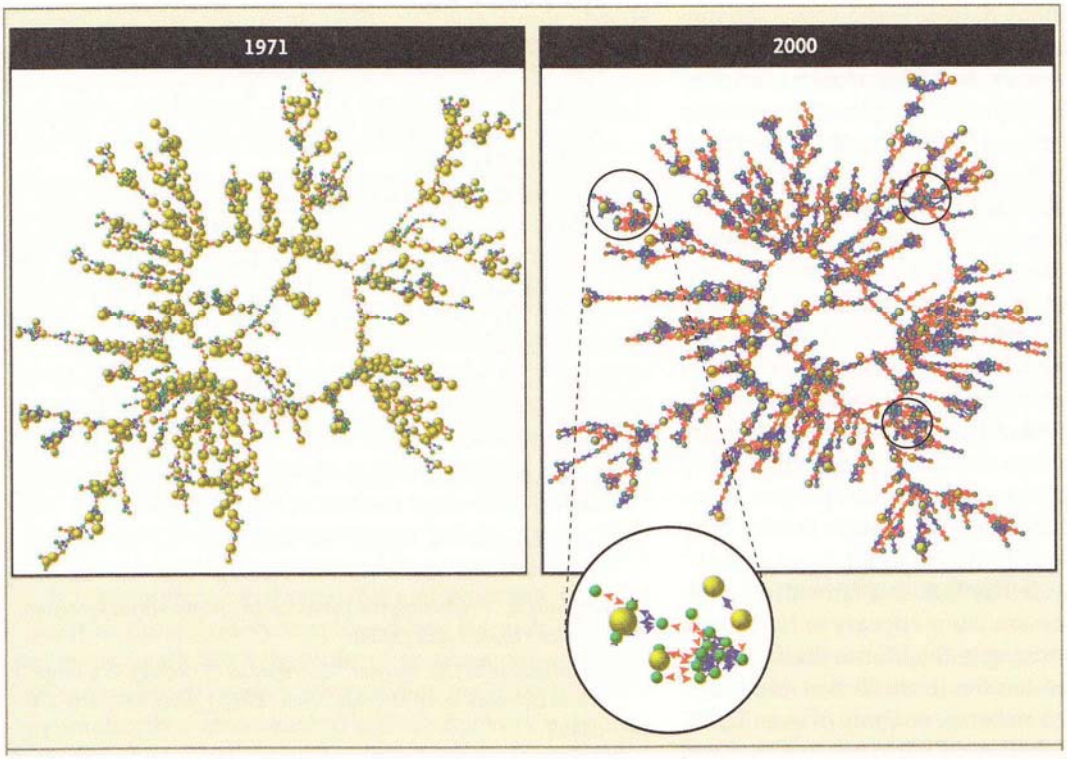


Fig. 1.8
Networks and complexity. Several types of network which can be 'defined' by using different levels of complexity.



Part of the social network for a medical study conducted between 1971 (left) and 2000 (right). Each circle represents a person: yellow borders denote women, and red borders men. The interior colour and size indicate daily cigarette consumption – yellow for smokers (with a size proportional to intake), green for non-smokers. Orange links denote a friendship or marital tie, purple a familial tie. By 2000, most smokers appear at the peripheries of the network, in relatively small subgroups. The black circles in the 2000 network show some densely connected clusters of predominantly non-smokers, with a few smokers on the periphery. (Credit: from N. A. Christakis & J. H. Fowler, *New Engl. J. Med.* **358**, 2249–2258 (2008).)

Fig. 1.9
Road network. The international road network in Europe. (http://en.wikipedia.org/wiki/Image:International_E_Road_Network.pgn.)

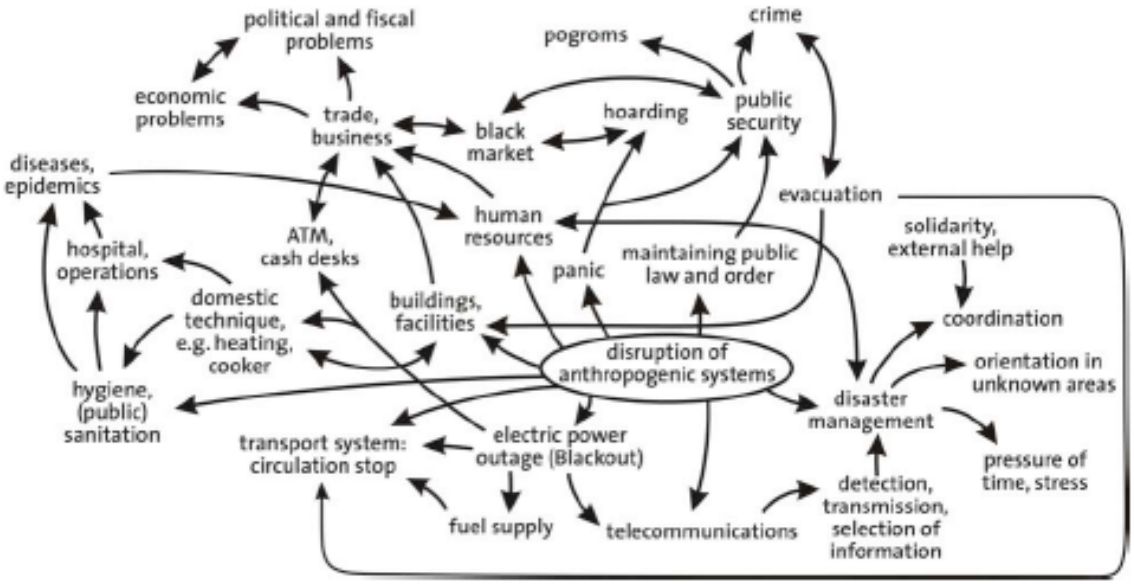
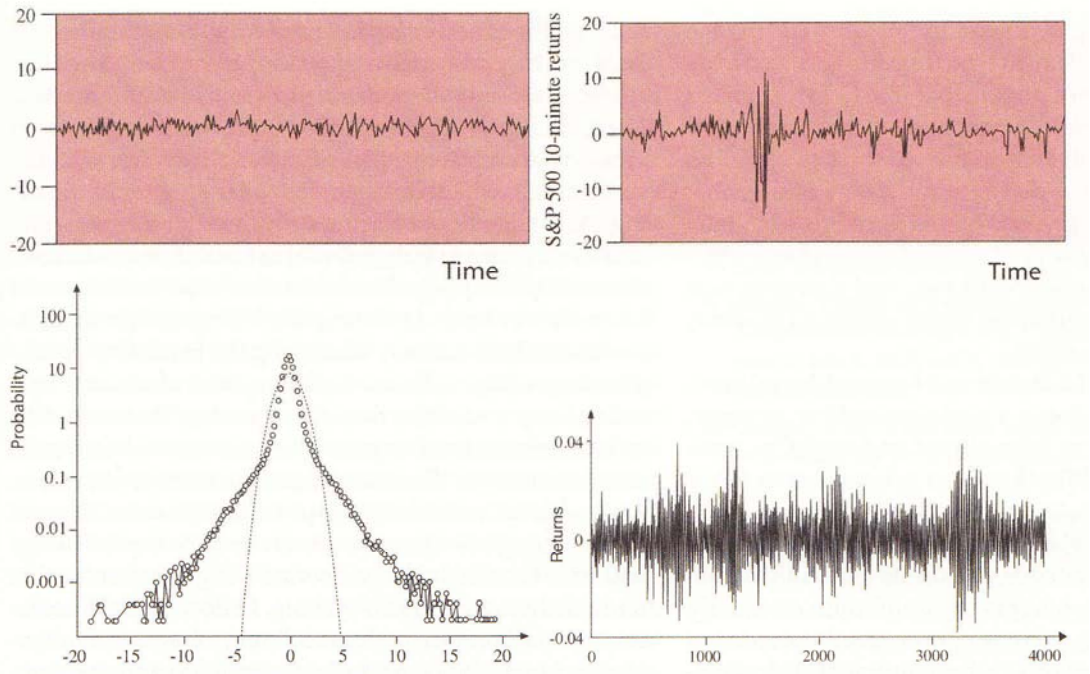


Illustration of cascading effects in techno-socio-economic-environmental systems, which may be triggered by the disruption (over-critical perturbation) of an anthropogenic system. A more detailed picture can be given for specific disasters. Note that the largest financial damage of most disasters is caused by such cascading effects.



In traditional models, economic fluctuations are often assumed to be like white noise (top left). But in fact they tend to have bigger spikes than that (top right). A plot of the statistical distribution (lower left, here for fluctuations of the Standard & Poor's 500 market index) shows how different the real variability is from white noise, which would give the dashed curve. Agent-based economic models typically produce more realistic fluctuations with more large spikes: an example is shown in the lower right.

- The dynamics of strongly connected systems with positive feedbacks is faster.
- Extreme events occur more often and can impact the whole system.
- Self-organization and strong correlations dominate the dynamics of the system.
- The system behaviour is often counter-intuitive, and unwanted feedback or side effects are typical.
- The system behaviour is hard to predict, and planning for the future may not be possible.
- Opportunities for external control are very limited.
- Even the most powerful computers cannot perform an optimization of the system behaviour in real time, as the number of interacting system elements is too large.
- The competition for limited resources implies reduced redundancies in the system and a larger vulnerability to random failures or external shocks.
- The loss of predictability and control lead to an erosion of trust in private and public institutions, which in turn can lead to social, political, or economic destabilization.