

14. KOMPLEKSSÜSTEEMID

14.1 Lihtsus ja keerukus

Definitsioonid

Lihtsus

Keerukus

Mudelid

Näited

References

1. G. Nicolis, C. Nicolis. Foundations of Complex Systems. World Scientific, Singapore, 2007.
2. P. Érdi. Complexity Explained. Springer, Berlin, 2008.
3. S. Strogatz. Sync: Rhythms of Nature, Rhythms of Ourselves. Allen Lane, 2003.
4. J. Gribbin. Deep Simplicity. Allen Lane, 2004.
5. M. Buchanan. Small World. Phoenix, 2003.
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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.

algorithmic complexity

an entity is complex if it embodies information that is hard to get

design complexity

control complexity

.....

ontological complexity

– deep complexity of material objects

semiotic complexity

complexity of our descriptions

which refer to the objects

also:

description complexity

d – complexity

ontological complexity

complexity of material objects

also:

interpretation complexity

i – complexity

structural

→

natural

functional

computational

parts → subparts → subsub ...
hierarchy



A complex system is composed of parts
interrelated in a way which is hard to understand.

↓
interactions
scaling

↓
model
prediction

conclusion:

different structure is observed at different
depth in the hierarchical description

pure “true” complete
order → complexity → disorder

ultimate complexity |

unpredictability

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

LIHTSUS

hierarhiad

rekursiivsed algoritmid

interaktsioon

mälu

...

KEERULISUS

MAAILM BASEERUB LIHTSATEL, KUID
MITTELINEAARSETEL REEGLITEL, MIS
ON RAKENDATUD AJAS KORDUVALT
JA REKURSIIVSELT

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

Terminoloogiast:

com (together) + **plectere** (to plait) = **complexity**

complexity – komplekssüsteemid, keerukus (terviklus?)

simplicity – lihtsus (kerge asi)

complexity *vrs* perplexity – komplekssüsteemid *vrs*

segasus (ka hämmeldus, nõutus, vassing)

deep simplicity – sügav lihtsus

emergence – esilekerkimine, emergents

Armin Toffler, 1984:

Üks kõige arenenum tänapäeva Lääne tsivilisatsiooni oskusi on tükeldamine: see on probleemide lahkamine nende kõige väiksemateks komponentideks või osadeks eesmärgiga neist aru saada ja lahendada.

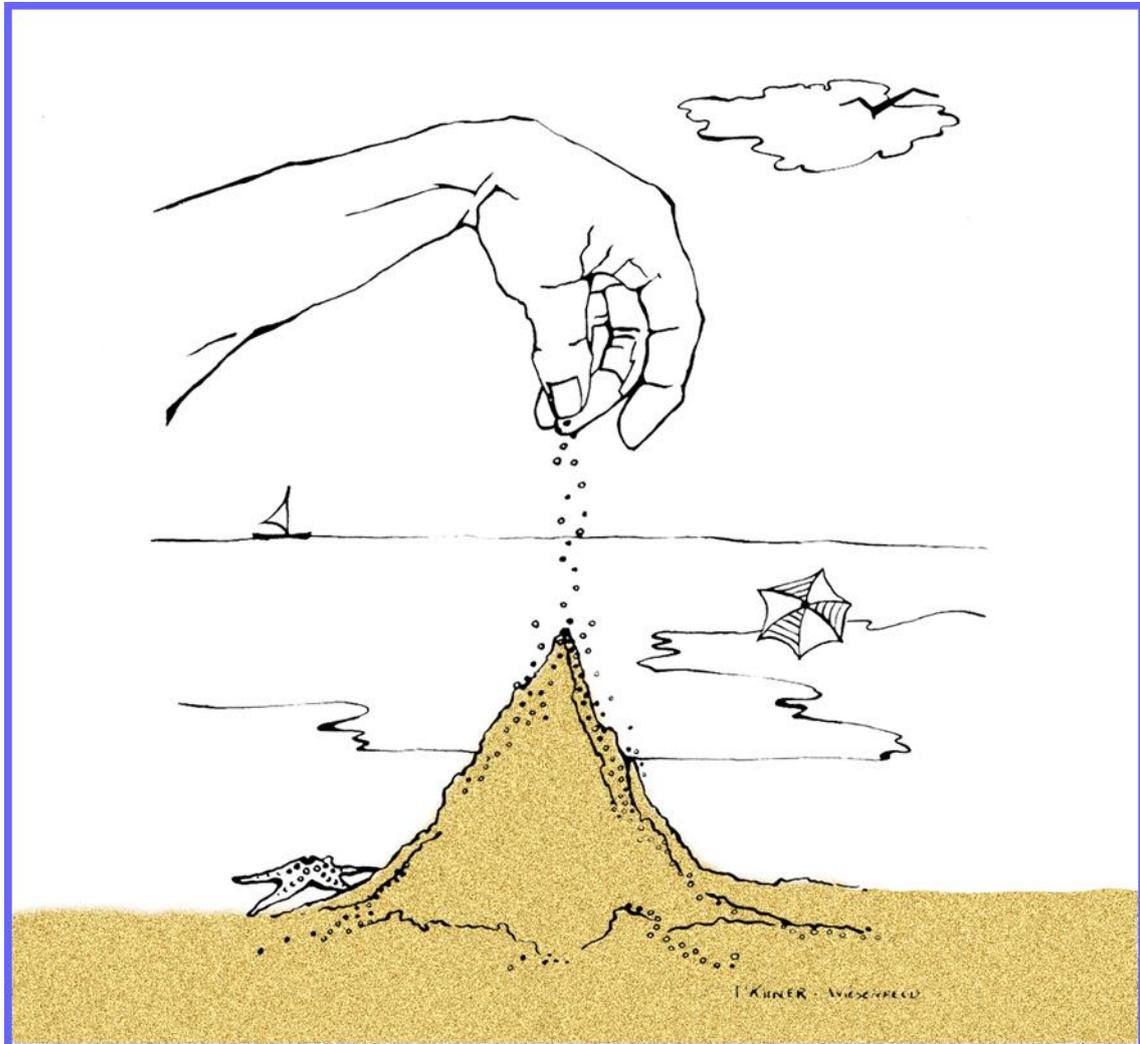
See oskus on meil ülihea.

Nii hea, et me sageli unustame osad panna tagasi kokku tervikuks.

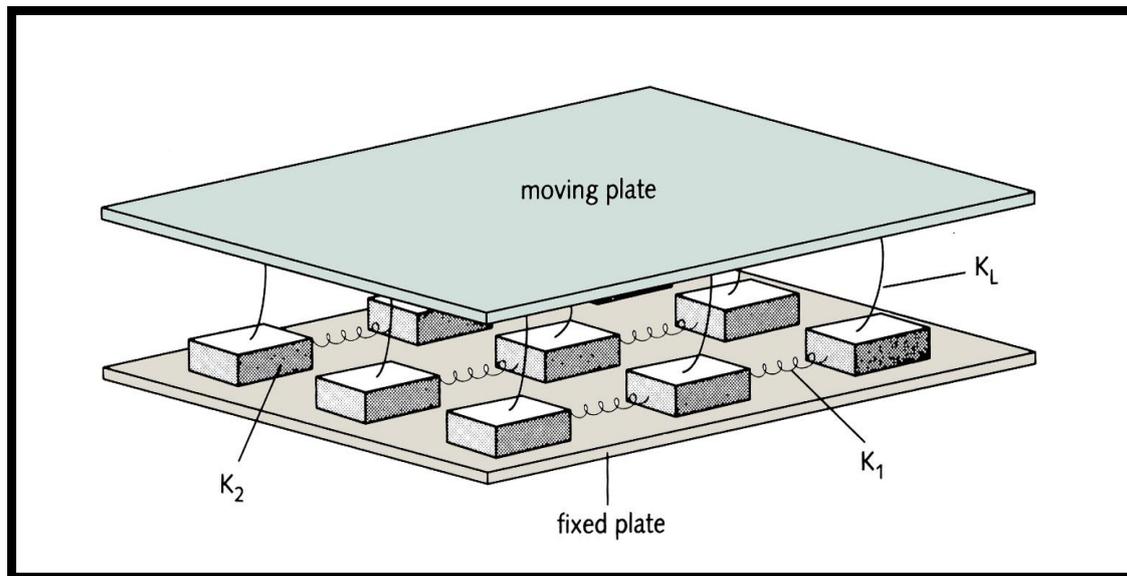
Komplekssüsteemide tunnused:

- komplekssüsteemid koosnevad paljudest komponentidest, mis omavahel seostatud ja mõjutavad üksteist, tihti esineb hierarhilisus;
- komplekssüsteemide käitumine on reeglina kirjeldatav mittelineaarsete seostega (ei kehti võrdelisus);
- komplekssüsteemid võivad olla iseorganiseeruvad uuteks struktuurideks uute omadustega, mis pole otseselt tuletatavad komponentide omadustest;
- komplekssüsteemid võivad omada mälu (st mäletavad, mis juhtus minevikus) ja olla adaptiivsed;
- komplekssüsteemid on ajas muutuvad ja tihti termodünaamilises mõttes mitte-tasakaalulised;
- komplekssüsteemide lokaalsed muutused arenevad tihti globaalseteks;
- komplekssüsteemid muutused toimuvad tihti korra ja kaose piirimail ja väikesed süsteemi alghäiritused võivad tekitada globaalseid muutusi.

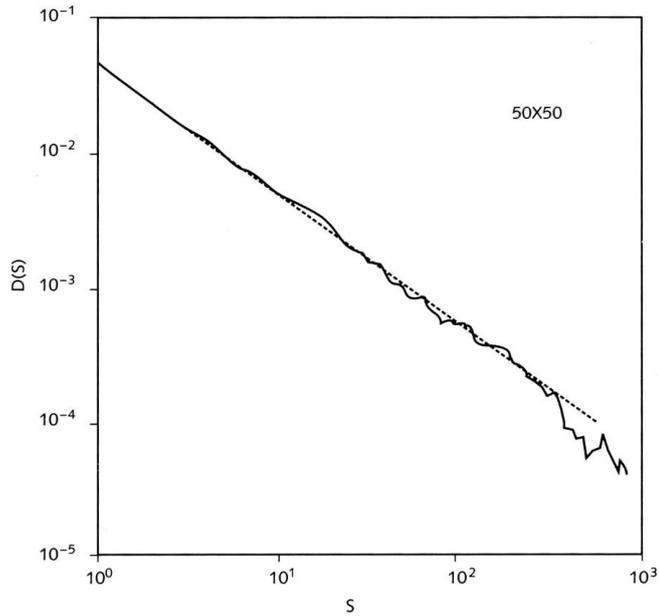
Mudelnäited: Per Bak, liivakuhik



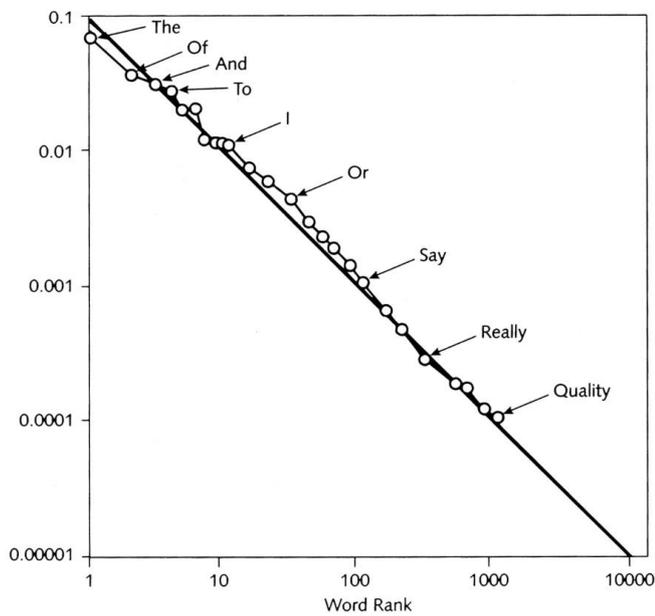
Mudelnäited: Burrige-Knopoffi maavärina mudel



Astmeseadus:



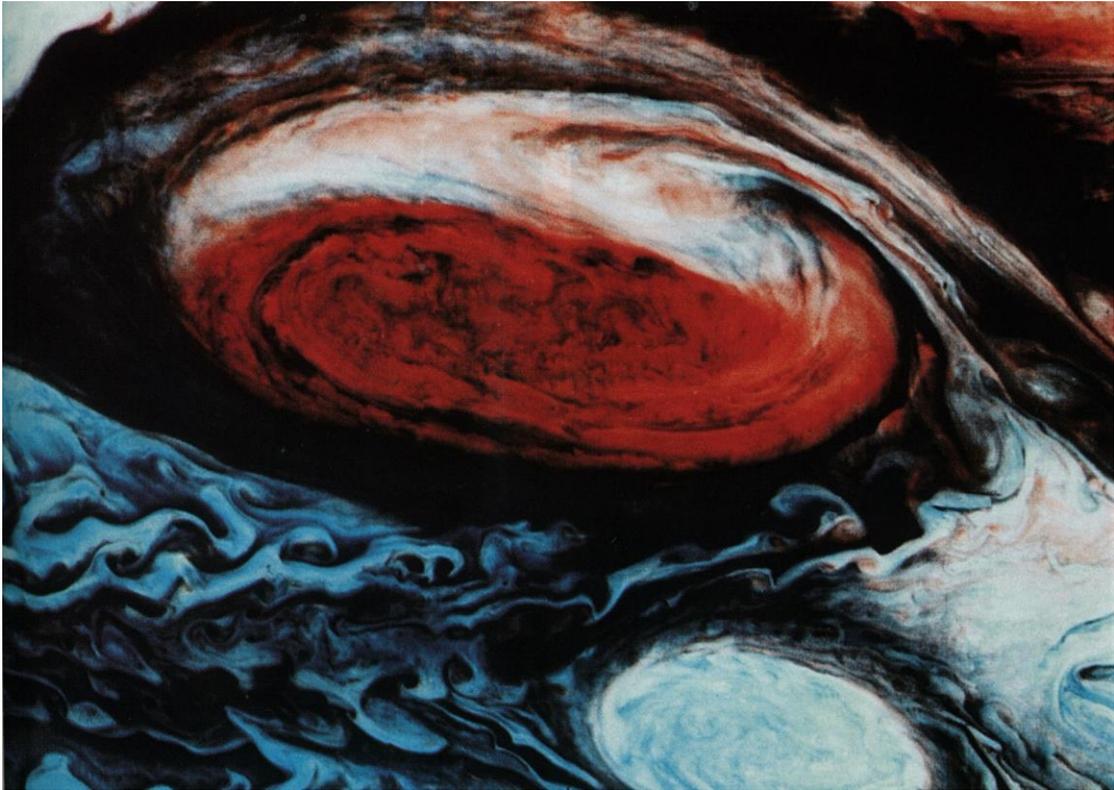
Size distribution of avalanches in systems of coupled pendulums or, equivalently, in the sandpile model. The figure shows how many avalanches there are of each size, on a logarithmic plot. The distribution is a power law with exponent 1.1. This is our very first plot. By performing longer simulations on bigger system one can extend the range of the power law.



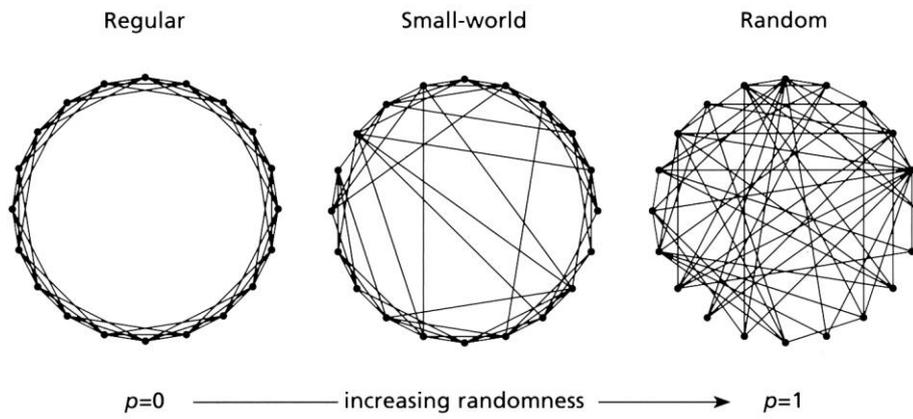
Zipf's Law for the English language.

Continued (b) Ranking of words in the English language. The curve shows how many words appear with more than a given frequency.

Mudelnäited: Jupiteri Suur Punane Laik



Mudelnäited: Strogatz-Watts'i väike maailm



Mis on neil ühist:

astmeseadus, mastaabiinvariantsus, lokaalsed
vrs globaalsed muutused ja tagasiside, ise-organiseeruvus
ehk emergents, tugev sõltuvus algandmetest,

(vt tunnused)

emergents: protsess, milles interaktiivsete lokaalsete
protsesside tulemusel tekivad globaalsed struktuurid või
mustrid. Need struktuurid või mustrid pole kirjeldatavad
või ennustatavad üksikute protsesside (osade) käitumise
või omaduste põhjal.

Vrdl I. Prigogine – hajuvad ehk dissipatiivsed
struktuurid

matemaatiline aparaat olemas ja arenemas, rakenduste
arv kasvab, kuid ...

Loodus- ja tehissüsteemide analüüs:

atmosfäärifüüsika ja kliima, biosüsteemide
iseorganiseerumine, närvitalitus ja südamerütmid, ...
internet, sotsiaalsed süsteemid,...

Per Bak: majandus on sarnane liivakuhiku käitumisega,
sest tegemist diskreetsete agentide, so isikute või
ettevõtete otsustega

tehissüsteemid: proaktiivsed arvutisüsteemid,
interaktiivsed situatsiooniteadlikud arvutusmudelid,
spontaanvõrgud, ...

rakendused: meditsiiniseadmed, tehnoloogiliste
protsesside juhtimine, majanduse poliitika ja sotsiaalsete
protsesside modelleerimine,...

Mis on riik?

Kas riik koosneb osadest, millised need on ja kas osad peavad moodustama terviku?

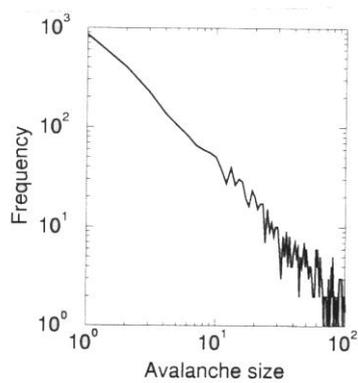
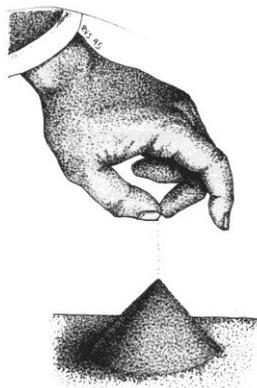
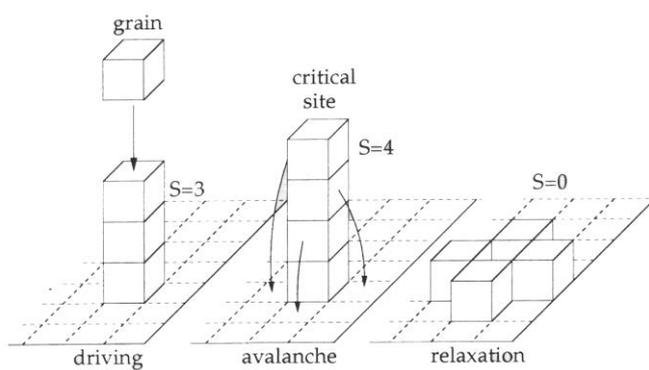
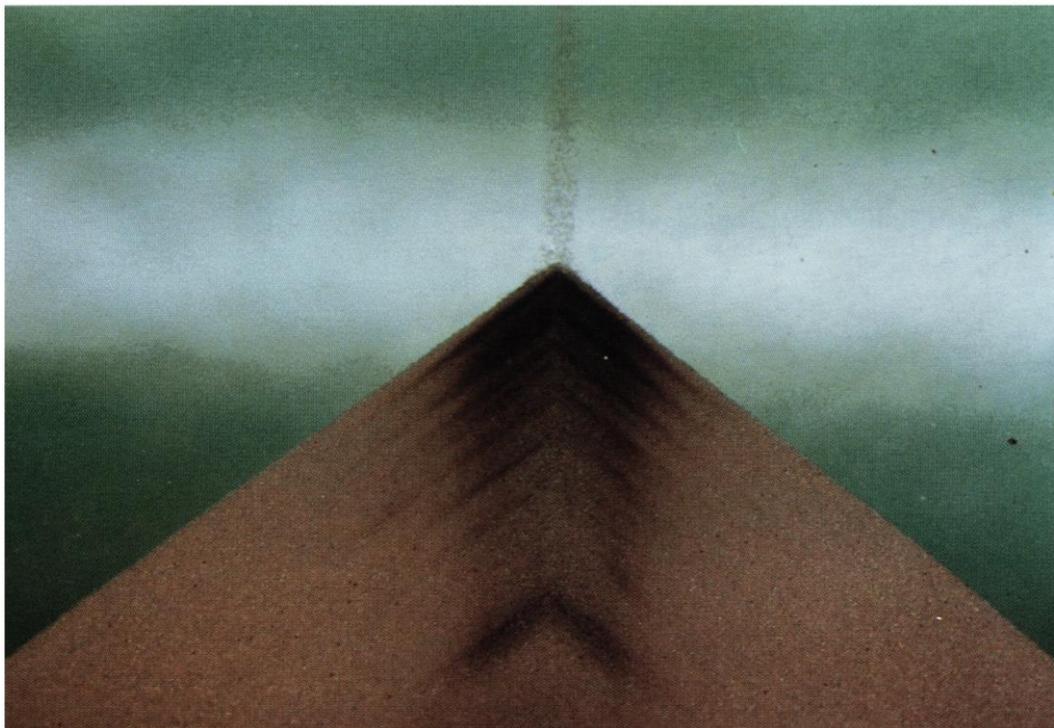
Kas osad riigis kui tervikus on seostatud ja mis sellest järgneb?

Milline on informatiivse seostatuse ja seda saatva müra tähtsus?

Kes analüüsib riiki kui kompleksüsteemi? On see üldse modelleeritav?

Kuidas hinnata paljude otsuste ja tegevusstrateegiate mõju ja seostatust?

Liivakuhik, kuidas tekivad varingud?



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

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

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

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

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

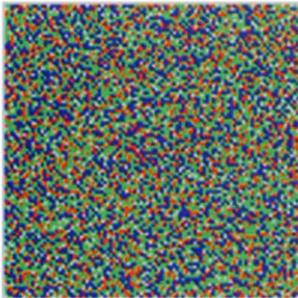
1	2	1	3	3
2	4	0	1	1
1	3	3	2	3
3	2	1	0	2
0	2	3	2	2

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

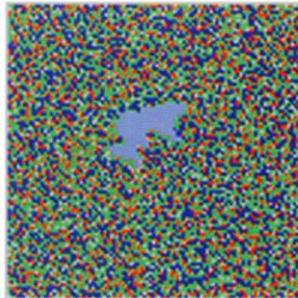
1	3	1	3	3
3	1	1	1	1
2	0	4	2	3
3	3	1	0	2
0	2	3	2	2

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

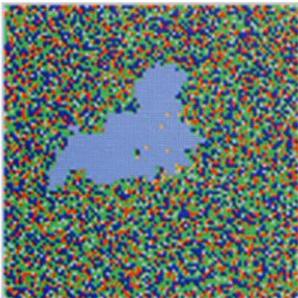
1	3	1	3	3
3				1
2				3
3	3			2
0	2	3	2	2



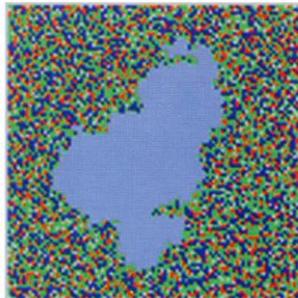
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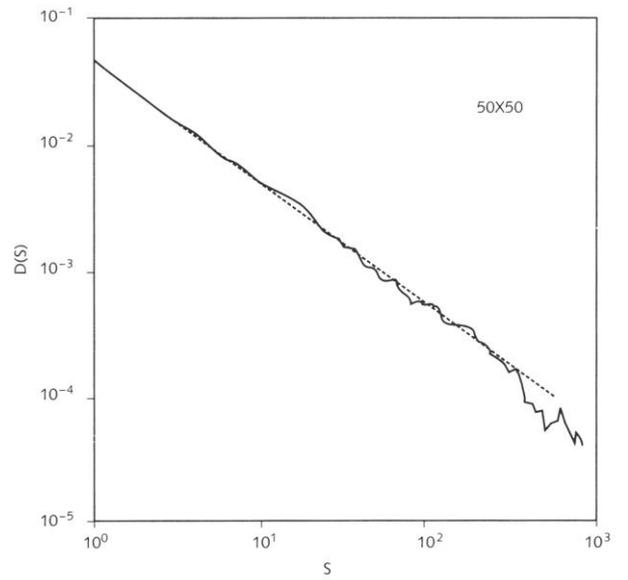
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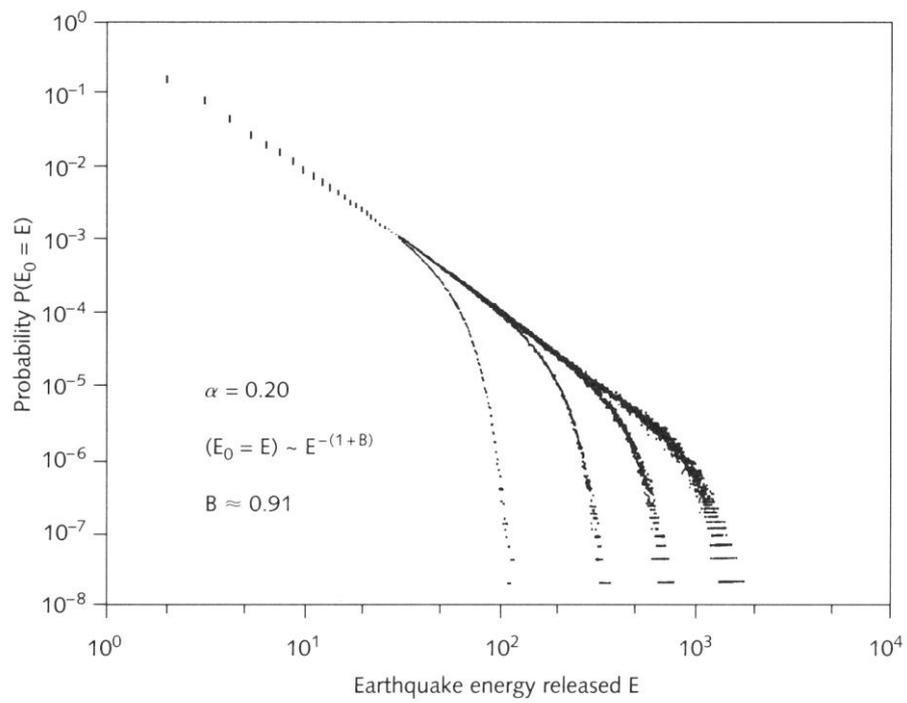
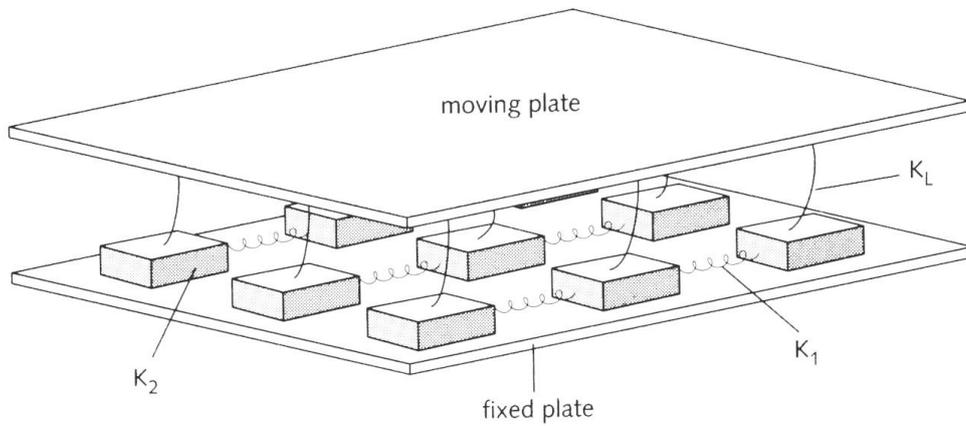
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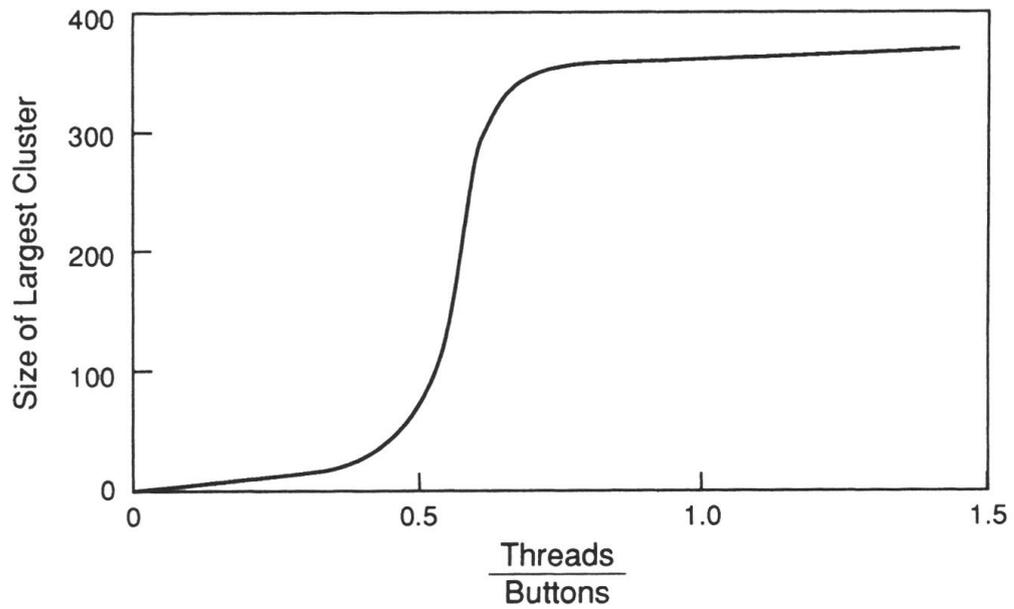
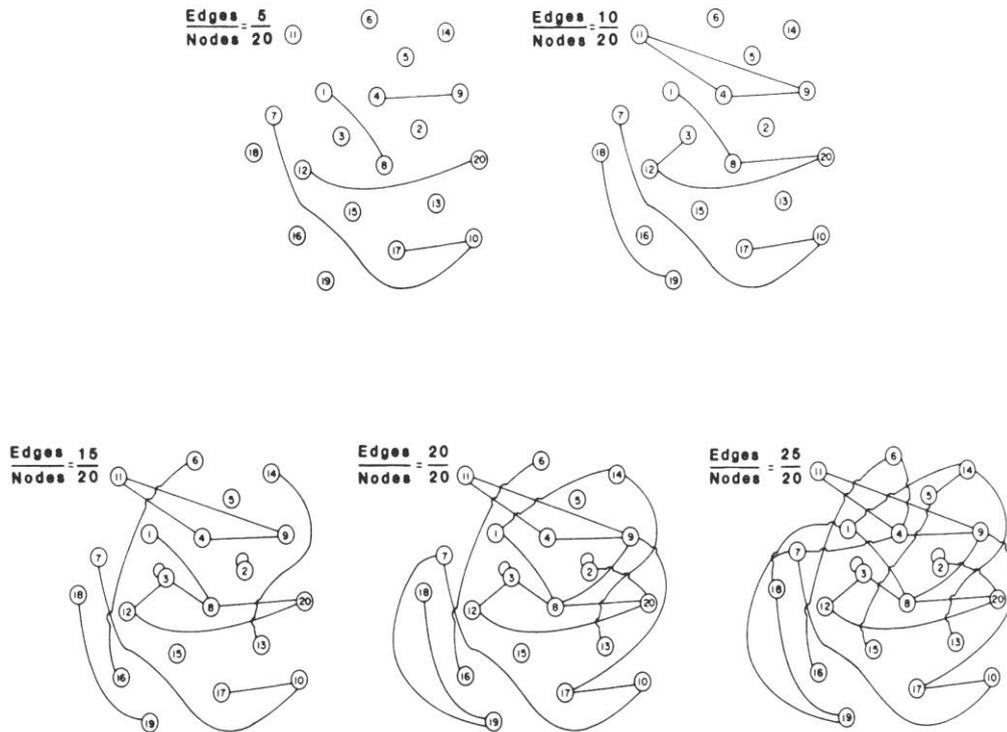
d



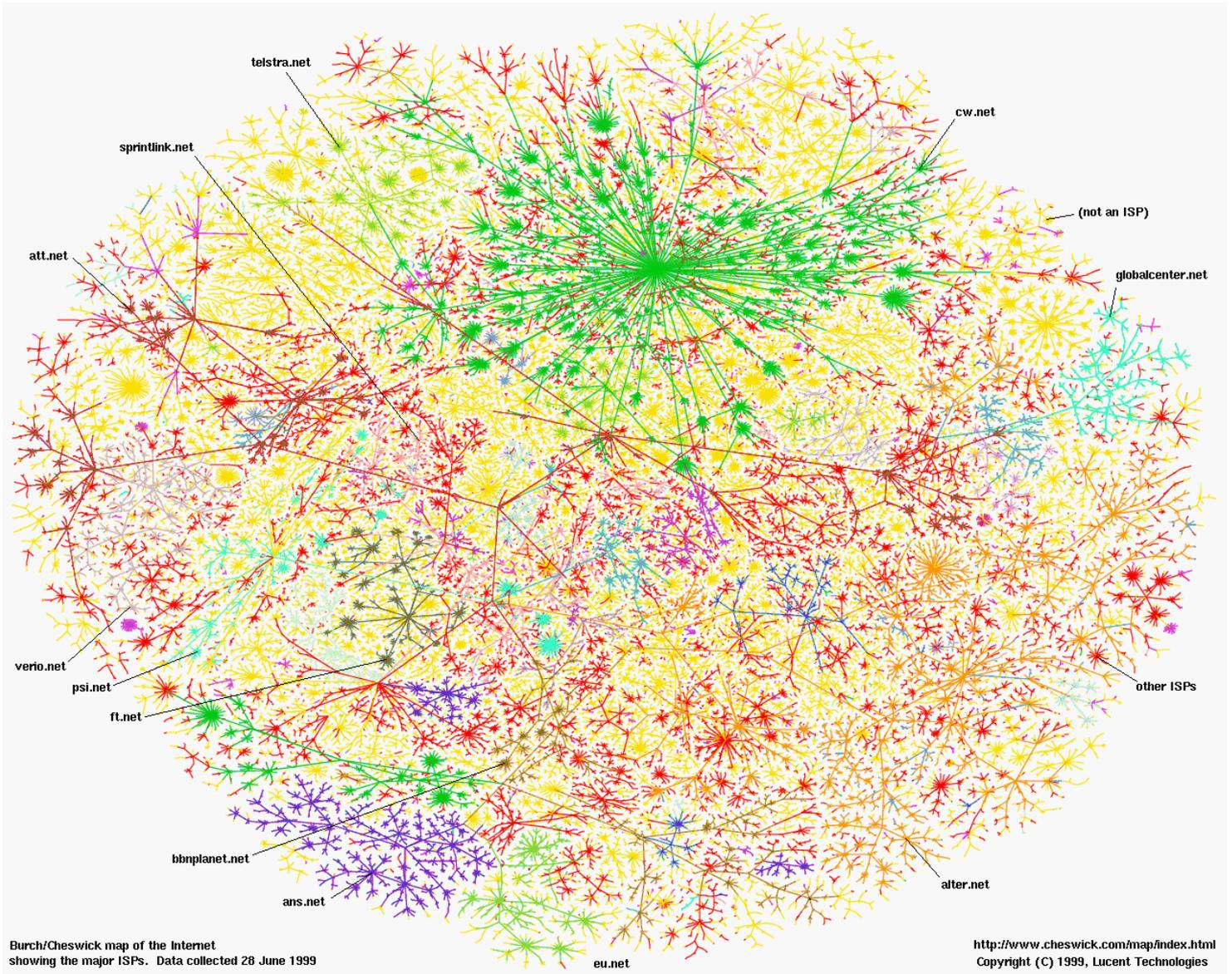
Maavärinate blokkimudel, Burridge-Knopoff



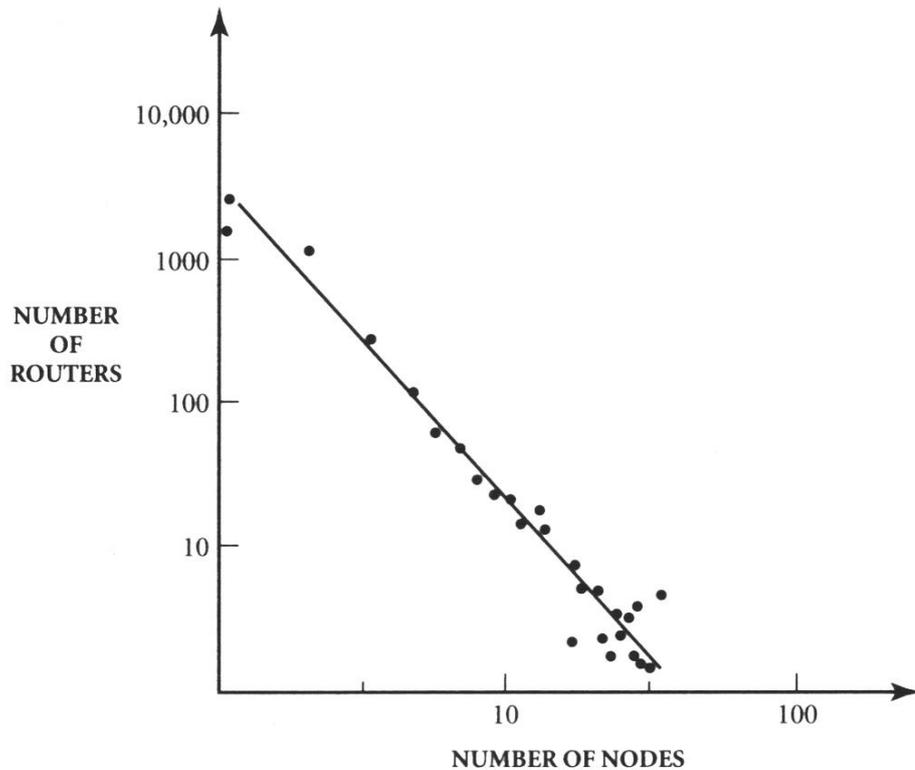
Võrgustikud, kujunemine



Internet, skeem



Internet, astmerida



Nähtused

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

Sünkroonsus

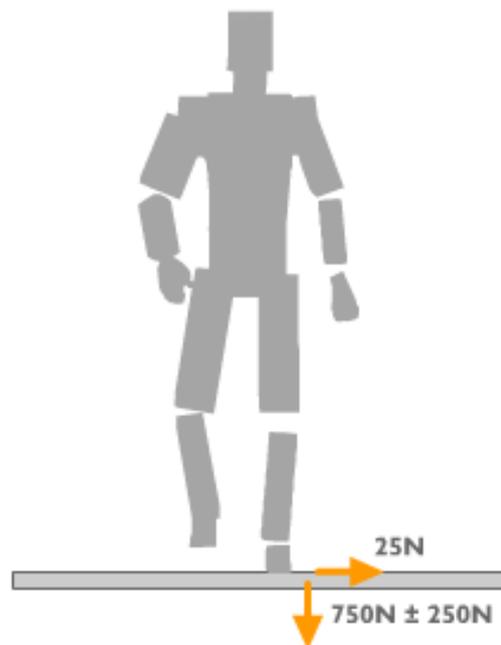
loodus:

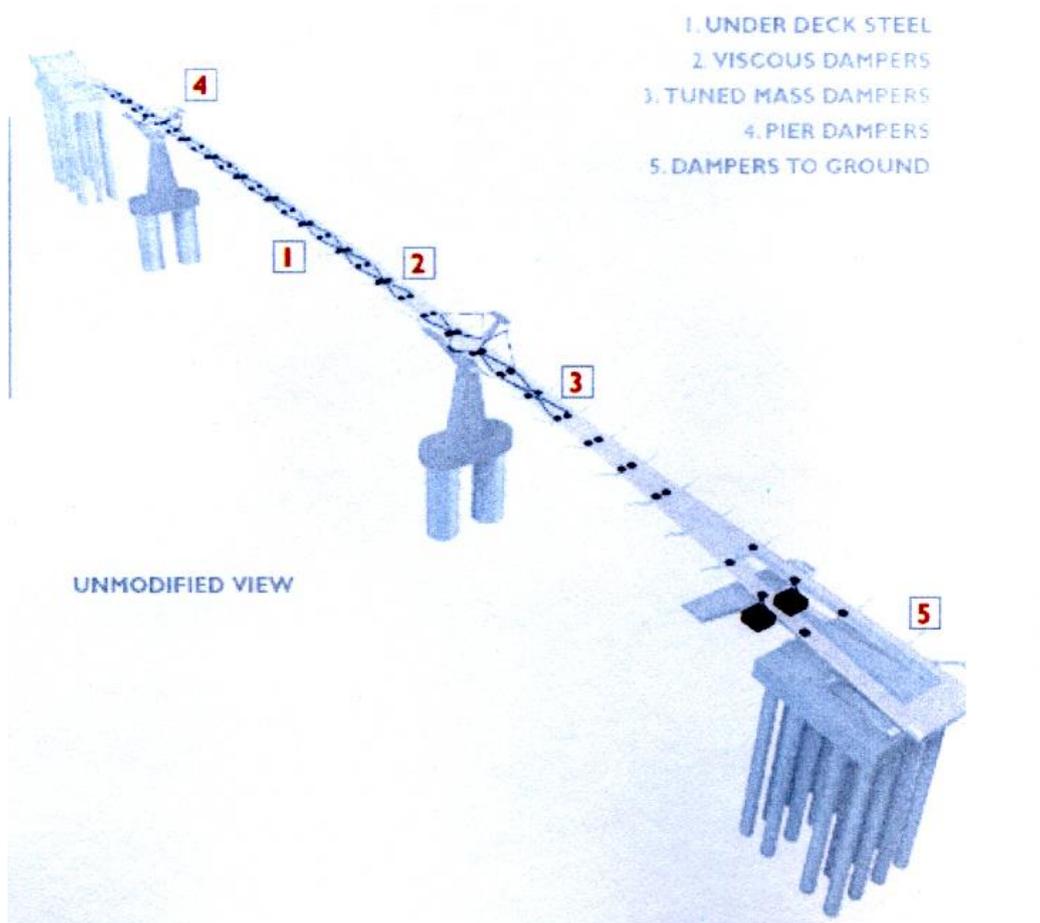
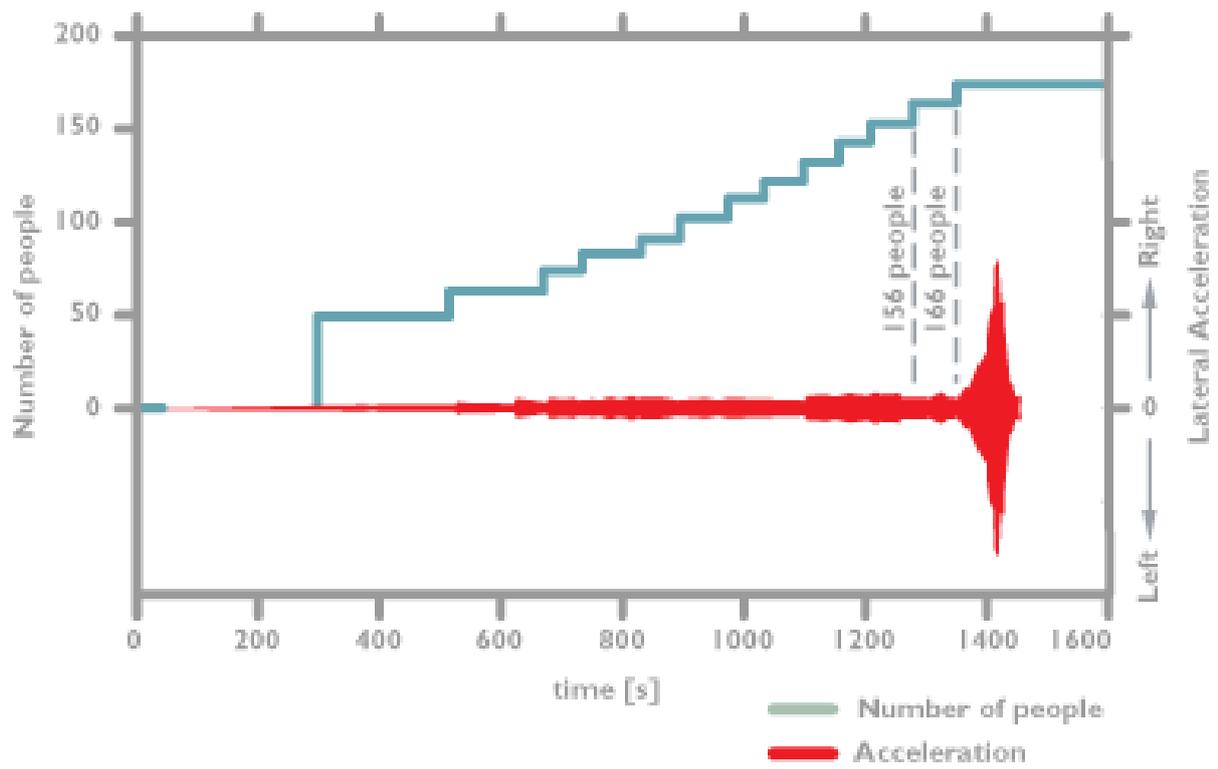
- ◆ jaanimardikad – fireflies
- ◆ südame sinuatriaalsõlm

tehissüsteemid:

- ◆ Huygensi pendlid
- ◆ Josephsoni efektid
- ◆ Millenium Bridge Londonis

Sünkroonsus – Millenium Bridge, London





Mittelineaarsus

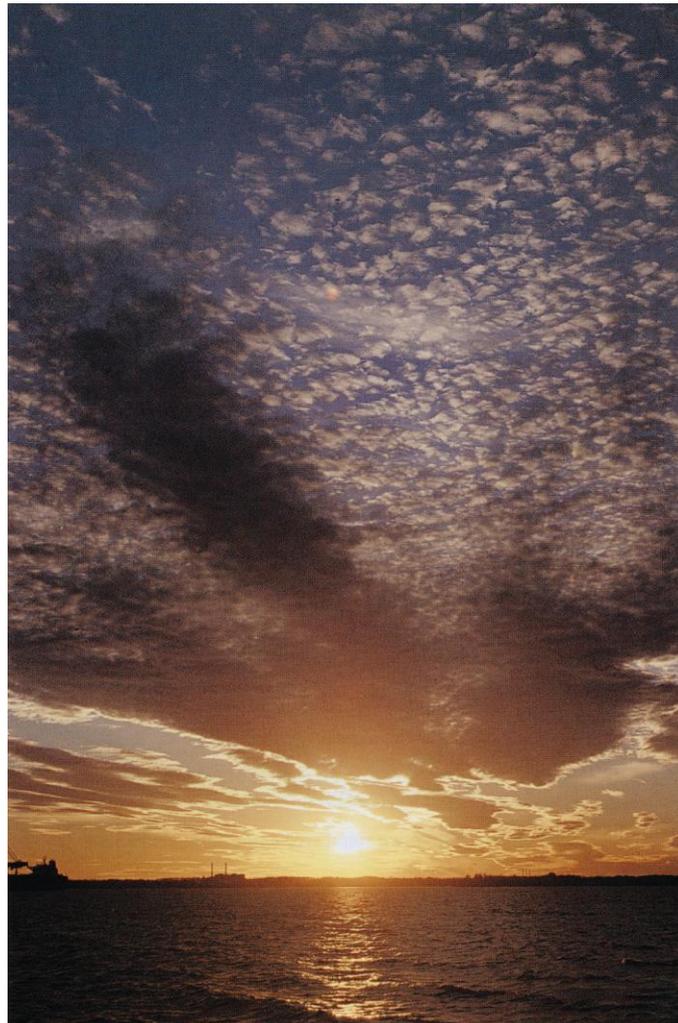
Lihtne seletus – puuduvad võrdelised seosed
ehk:

Aristoteles: summa on suurem kui üksikosad kokkuliidetuna

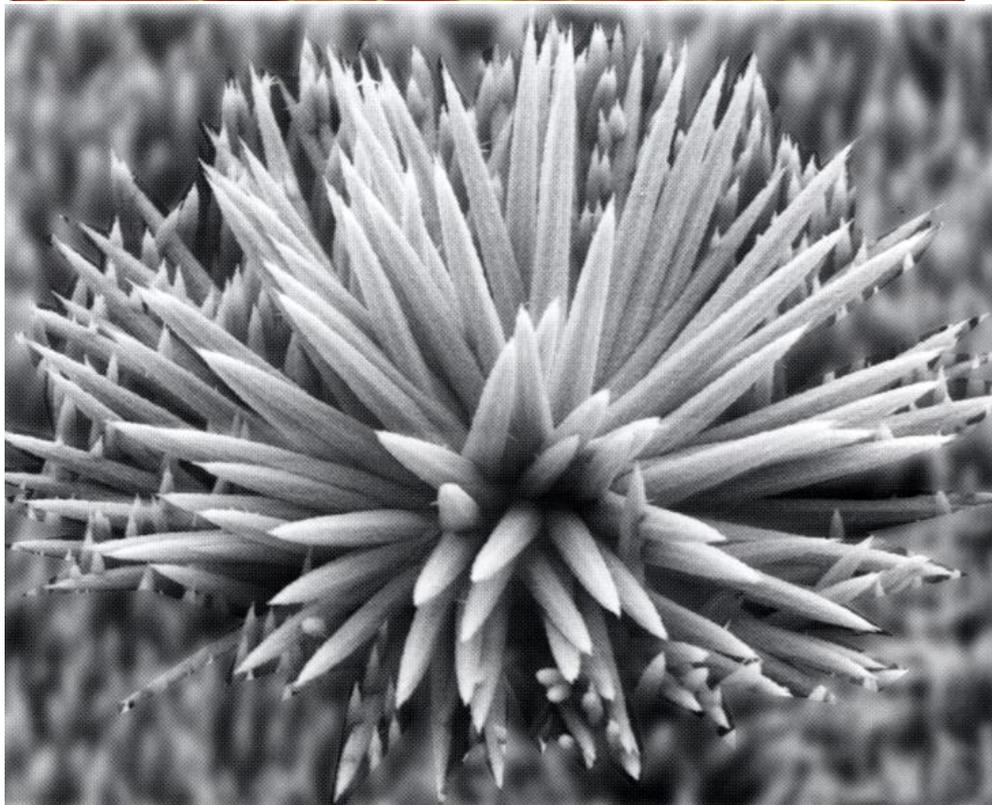
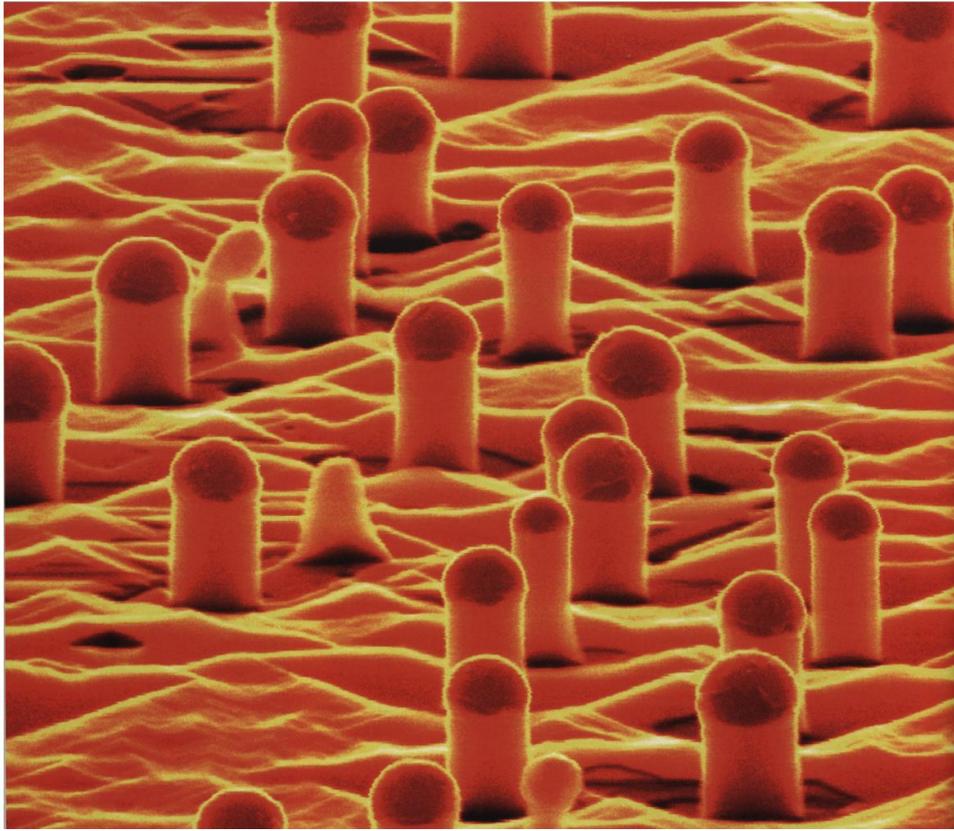
Hundertwasser: sirgjoon viib inimkonna mandumiseni....

Mandelbrot: pilved pole kerad, rannajooned pole kaared,
puukoor pole sile...

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



Keerukus



Kas intuitsioon töötab? Rakuautomaadid

