Impact Analysis

Impact Analysis

- For each intrusion it determines the loss if it is successful
- Depends upon
  - The resources the attacker can control
  - The processes using these resources
- It depends upon the attribute(s) that the attacker controls (confidentiality, ….)
- Some loss
  - Cannot be quantified (eg human lifes)
  - Are very difficult to estimate (image and so on)

Impact Analysis

- It requires information about the processes of the organization that are using the data
- This information may be collected by interviews
- The impact
  - also depends upon the time to discover and remediate the intrusion
  - is a function of which attacker controls some resources (eg organized crime vs terrorism)

Impact Analysis

- Proper questions to ask an organization
  - How long could the business continue to operate while that system is down?
  - What would be the opportunity cost of that downtime?
  - What would be the real costs associated with bringing that system back?
- The answers depend upon the role of the ICT system in an organization, the more critical the system, the larger the impact

Probability Distribution

- An exact, numerical extimate of the impact is rather difficult
- The impact is modelled as a random variable with a probability distribution and the impact is the average of the distribution
- A very popular distribution is the normal one

$$f(y) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{\frac{-(y-\mu)^2}{2\sigma^2}}$$

Probability of an impact =y

The impact is centered around the average μ

Normal distribution

- Several nice mathematical properties
- Central limit theorem:
  - The impact is the sum of distinct contributions, each with its own probability distribution
  - The limit of the sum of distinct distributions is a normal distribution
- Even the error in the analysis may be normally distributed

Normal distribution

- Thin tail = an exponential decrease in the value of the impact
- Values at a distance larger than 3 / 4 standard deviations from the average value may be neglected because their probability is very low
- Centered around the average
- Sometime it is too optimistic

Normal Distribution

- “mild” randomness (Mandelbrot) or Mediocristan (Taleb)
- Mild randomness is denoted by the thin tails
- Models a process that is the sum of several other processes and where an increase of the output of a process may compensate a decrease in the output of the other ones (sum of distances from the average is zero, proper of physics)
- Consider the height of a person, for physical reasons the possible values belong to a small rangee, differences are bounded

Heavy tailed

- A distinct case is the one where there is an impact value such that if a threat agent can build an intrusion that achieves that impact, then she can achieve any impact
- Two alternative definitions of this case are

i) $\lim_{\delta\to\infty}$ Prob(X>δ+h) / Prob(X>δ) = 1 $\forall$ h

Or

ii) $\forall$ h $\exists$ w | v> w then Prob(X> h*v)/Prob(X>v) does not depends upon h

Example: consider the range of the amount of money a person owns. There are no constrains to buond the difference between two person

Heavy tailed

- The threat can achieve any impact if she fully control the system and the owner cannot regain control of the system
- In these cases, the impact cannot be model by a normal distribution

Power-law & Heavy Tails

- Any probability distribution prob(imp) that satisfies

  $\text{prob(imp)} \propto \text{imp}^{-\alpha} = 1/\text{imp}^{\alpha}$ for $\text{imp} > \text{imp}_0$,

  $\alpha > 1$ is the "exponent" of the power law.
- The power-law behavior occurs for

  $$\text{imp} > \text{imp}_0$$

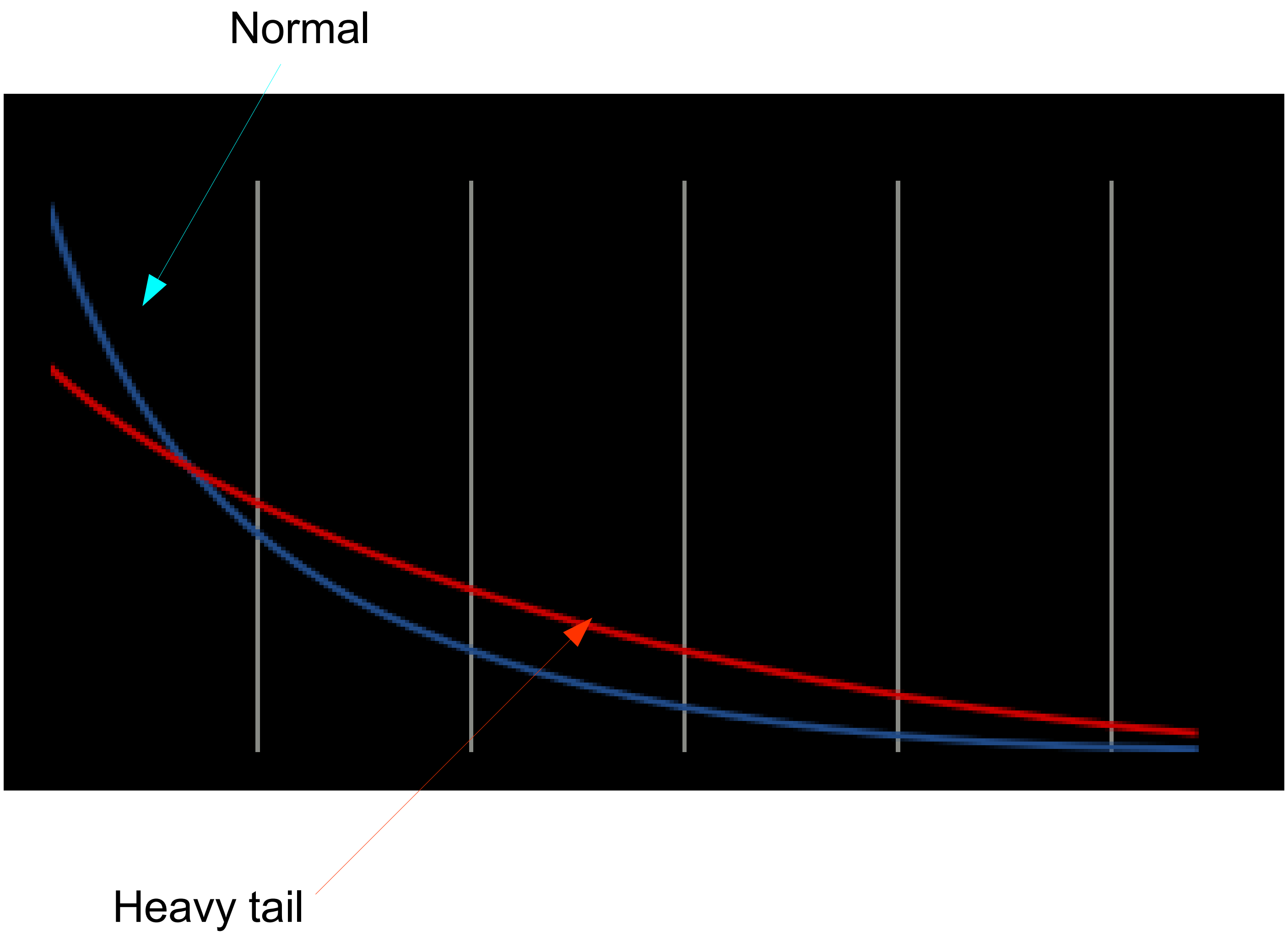
  the tail of the distribution, that is called an heavy tail,
- Extreme impacts are far more likely than in a Gaussian distribution, i.e. than in Mediocristan.

Heavy tailed

The power law is an heavy tailed law

- Probability distribution = $g(x)(1/x^{\alpha})$ $\alpha>1$
- If $\alpha<2$ all the moments (average, standard deviation, .. .) are unbounded
- If $2<\alpha<3$ only the average exists

Heavy Tail



Heavy tailed vs normal

- The impact of an attack that results in the knowledge of some credit card numbers.
  - Can be modelled through a normal law
  - We can introduce mechanisms to bound the impact such as the largest amount of expense in a day
- The impact of an attack against the server that stores all the credit card numbers
  - Cannot be bounded
  - Cannot be modelled through a normal law

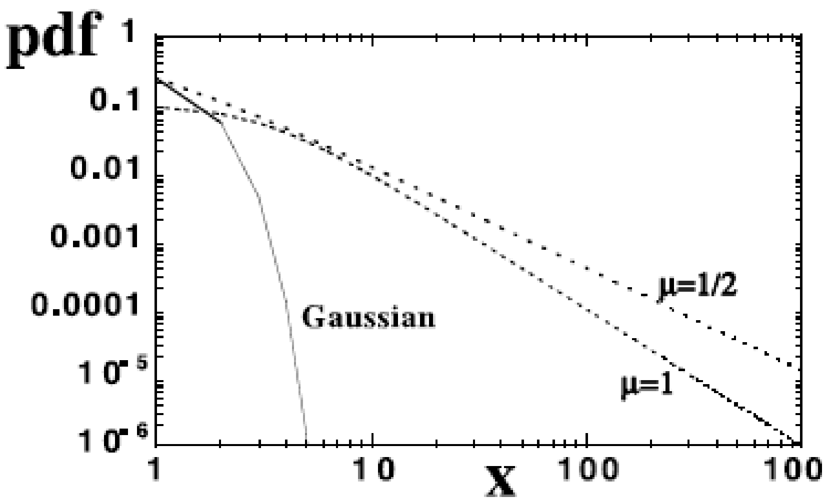
Examples

- Assume that 1.000 euros is the average loss if the number of a credit card is stolen
- If 100 credit card number are stolen, the impact has a normal distribution with an average equal to 1.000 x 100
- But if we lose a database with 1.000.000 credit card numbers, the impact has to be evaluated in a different way and we have an head tail
- The same happens if the attacker controls the system to block stolen credit cards

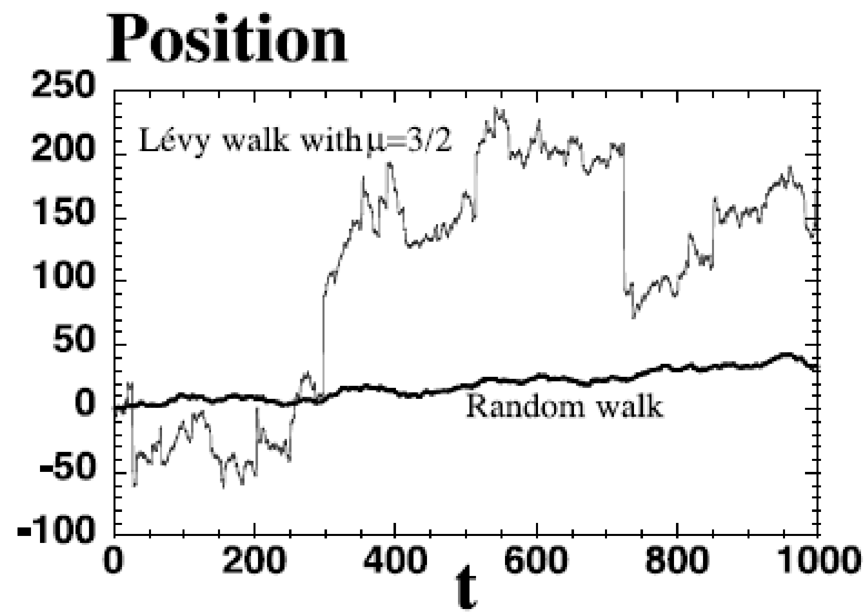
Other cases with power law

- To minimize the cost of an infrastructure, the designer may adopt strategies such preferential attachment or “the rich will become richer”
- This results in a interconnection structure described by a scale free graph where the number of connection of each node decreases with a power law
- The impact of an intelligent attack against such an infrastructure is modelled as
  - a power law
  - all the moments are unbounded

Power law vs normal



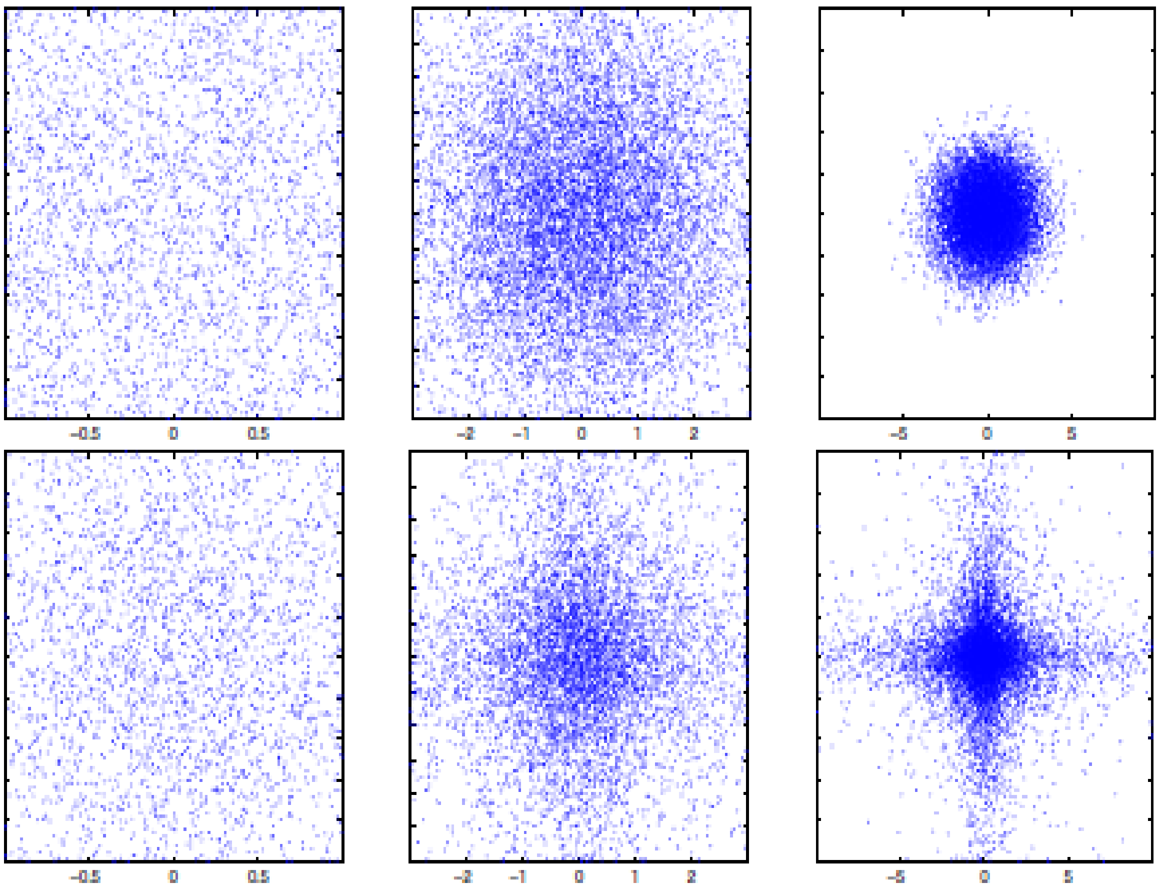
Curve in log-space



Random walks with a normal generation and a power law generation

Sornette, D. - Critical phenomena in natural sciences. Chaos, fractals, self-organization and disorder. Concepts and tools

Power law vs normal: scale is important



normale

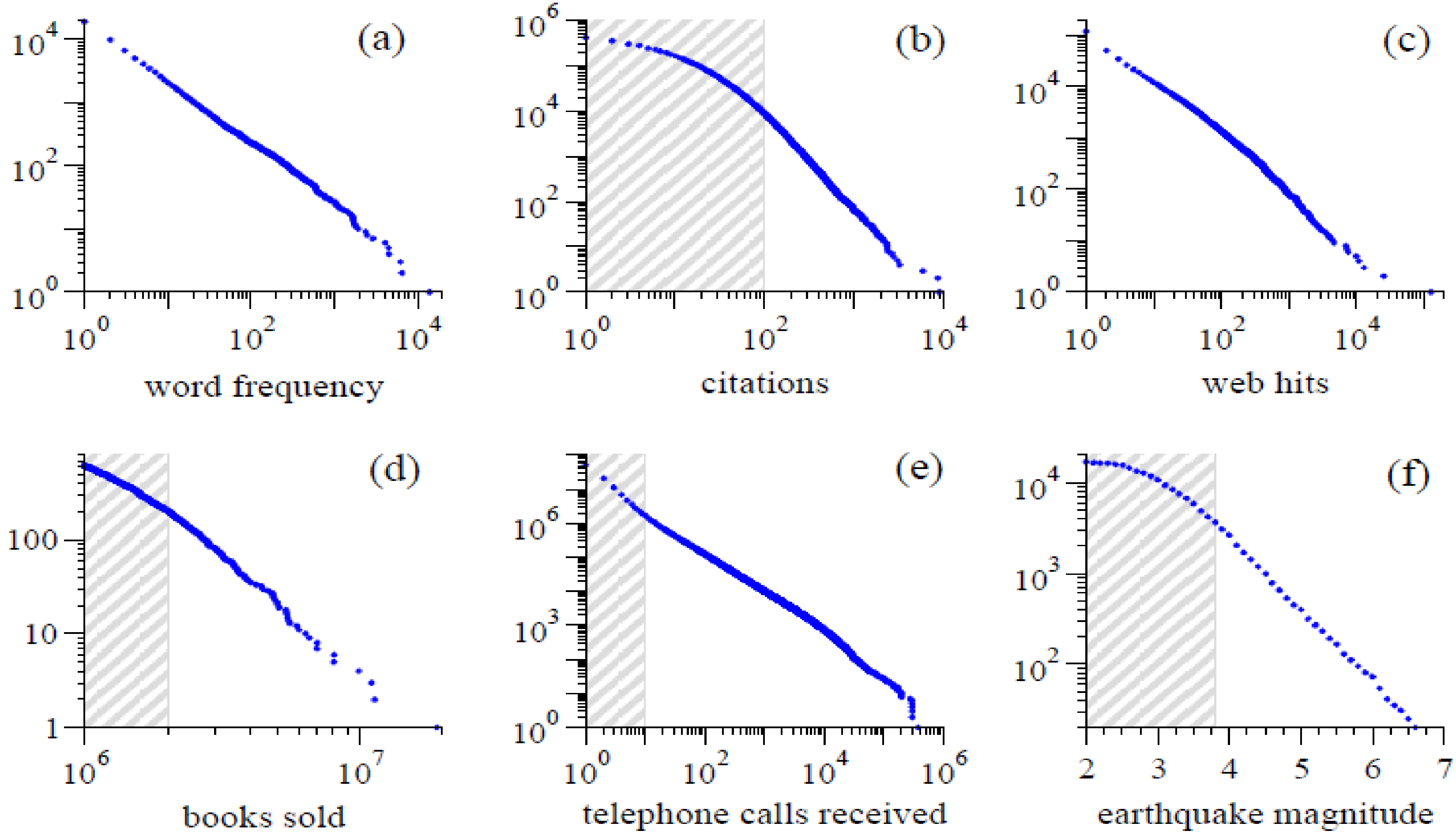
Power law

Random points generation with a normal or a power law
F.Clementi, T.Di Matteo, M.Gallegati “The power law tail exponent of income distribution
Physica, 2006

Power law vs normal

- The difference cannot be discovered in an experimental way because if the number of data available is very low this may result in a too small difference
- We have to decide according to the scenario of the intrusion and of the threat agent that implements the intrusion

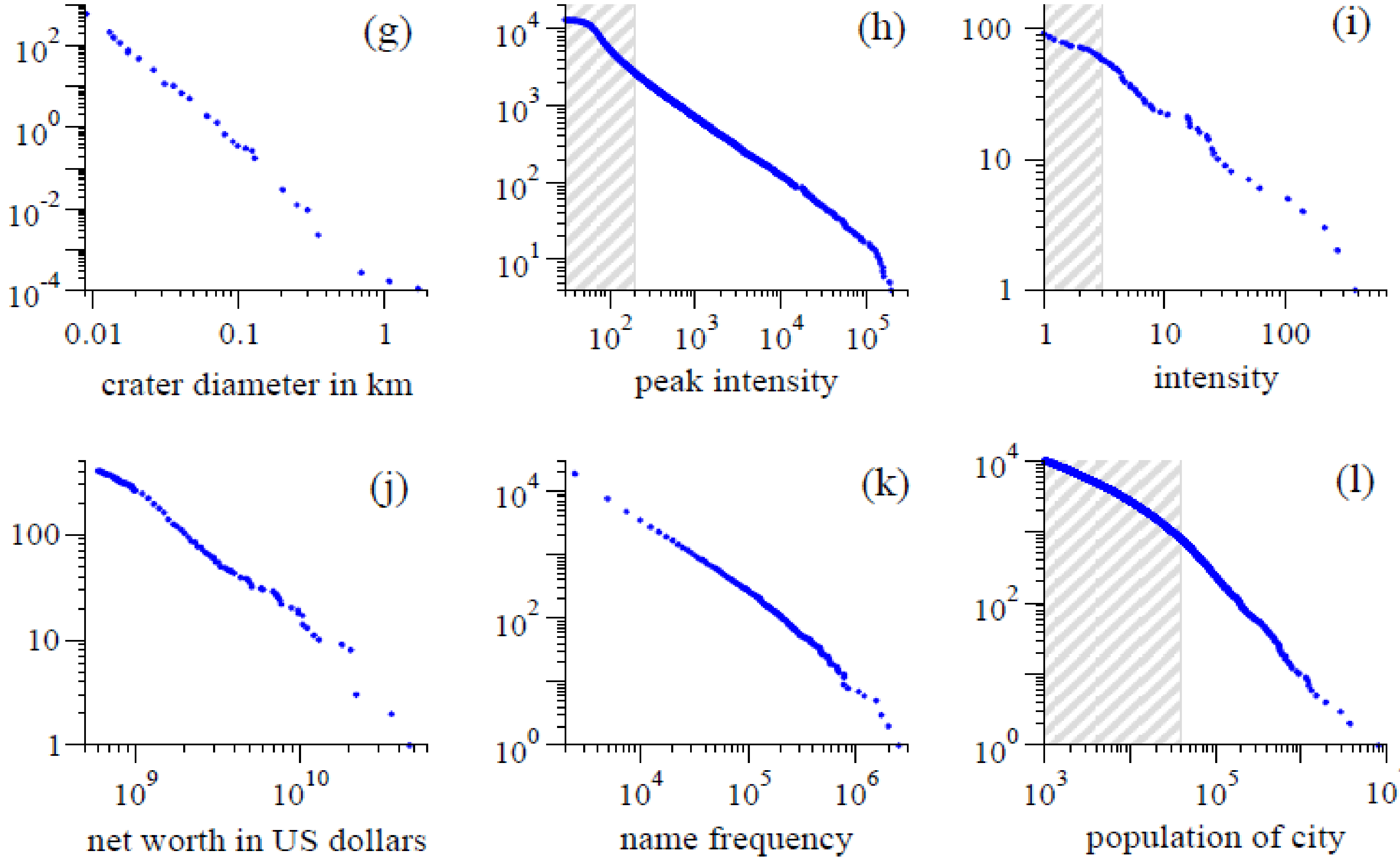
Some examples of a power law - I



Power laws, Pareto distributions and Zipf's law

M. E. J. Newman

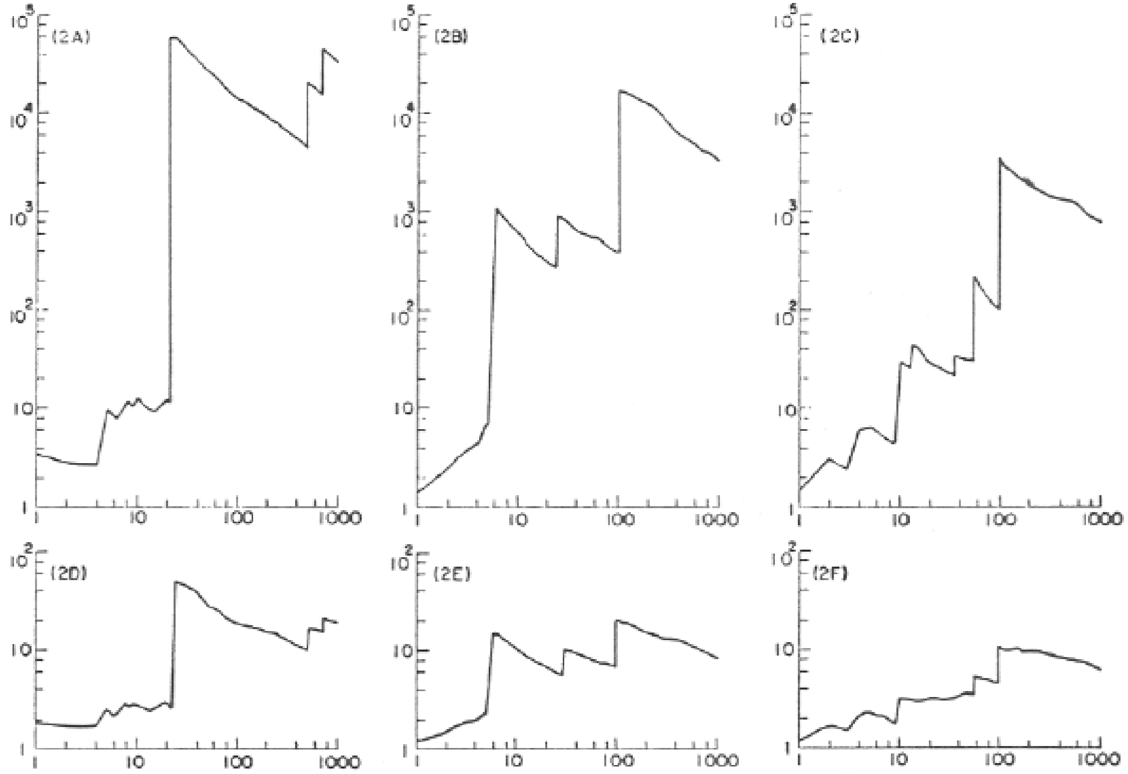
Other examples - II



Power laws, Pareto distributions and Zipf's law

M. E. J. Newman

Unbounded Moments



Average of a random sample, there is no convergence to a value

Power Law Vs ROI

- The previous discussion outlines the complexity of defining the ROI in this case because if the impact is described by a thick tail any countermeasure is cost effective
- The definition of a solution is rather complex even if a large amount of data is available

Cascade failures and heavy tails

The other risk at the level of national security is that of cascade failure which implicates services that are critical or merely pervasive. Cascade failure is where complexity and interdependence intersect, where unacknowledged correlation lies, where the heavy tails await. We already know that optimality and efficiency work counter to robustness and resilience and vice versa. We already know that a “control” strategy fails worse than a “resilience” strategy.

A Rubicon, Daniel E. Geer, Jr.

Aegis Series Paper No. 1801

Risk, Robustness and ROI

… systems designed for high performance naturally organize into highly structured, statistically unlikely states that are robust to perturbations they were designed to handle, yet fragile to rare perturbations and design flaws … high-performance engineering leads to systems that are robust to stresses for which they were designed but fragile to errors or unforeseen events

M.E.J. Newman, M. Girvan, and JD Farmer, “Optimal design, robustness, and risk aversion” Phys. Rev. Lett. 89, 028301 (2002)

Risk Management vs unbounded impact

- “forget optimization and embrace redundancy”
- Redundancy increase the complexity of attacks (redundancy in controls) and decrease the impact (redundant resources)
- Redundancy is effective only if independence among redundant resources is guaranteed
  ie the success probability of an attack against a copy does not influence the one of the same attack against a distinct copy