Fast, Cheap, and Out of Control?

Engineered Complex Systems

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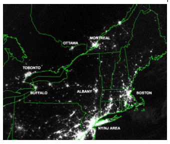
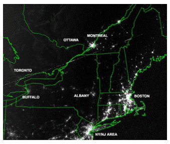
ECOL 496H

Unintended Emergent Behavior

- Millennium Bridge
- Power Outages

Wikipedia.org



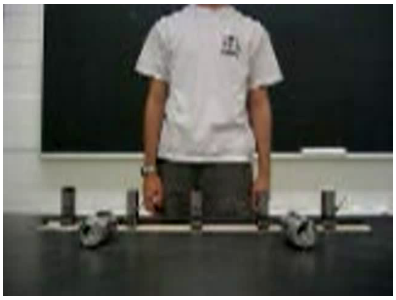


Dartmuth.edu

Millennium Bridge

Millennium Bridge
http://youtube.com/watch?v=eAXVa__XWZ8
Metronome Sync
http://youtube.com/watch?v=RMVxVbCIPjg

Spontaneous Sync



Youtube.com

Millennium Bridge

- Causes
  - Lateral resonance not accounted for
  - Human sync to resonance
- Consequences
  - Closure June 2000 to Feb 2002
  - £5 million

Power Outages

- Self-organized criticality
- Unavoidable?
- Mitigation Side Effects
  - Can increase probability of large-scale catastrophes
  - Forest fire model

Importance

- Critical services (medical, sewer, mass transit etc) depend on electricity
- Business depends on electricity
- Consumers depend on reliable electricity

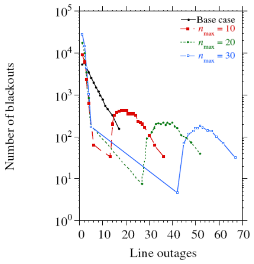
Mitigation Strategies

1. Increase critical number of individual line failures past which cascading failures occur
2. Strengthen power lines to better cope with spikes
3. Increase excess power margin

- Dobson tests these with the Oak Ridge-Pserc-Alaska model (OPA)

Increase Critical Number of Individual Line Failures

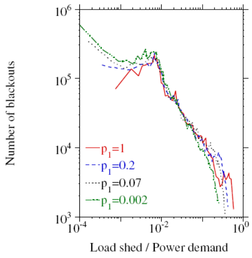
- Fewer small outages
- More large outages



Dobson et al. 2003

Increased Line Reliability

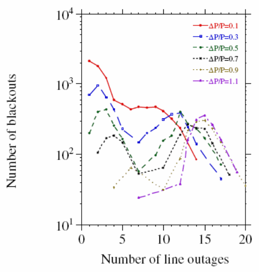
- Fewer large outages
- More small outages



Dobson et al. 2003

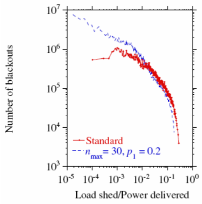
Increased Excess Power

- Fewer small outages
- More large outages



Combination of Increased Reliability and Critical Number

- No significant change
- Not economically feasible



Dobson et al.

Main Points

- Implementation of ideas to existing systems can't be taken at face value, they may have unintended, non-obvious repercussions
- A holistic approach needs to be taken to most modern problems to help prevent future failures.
  - This may in many cases require new methods of modeling which will begin to require more powerful computers to solve

Using Complexity Engineering

- Cheap systems
  - Easy to make
  - Easy to maintain
- Robust
  - Adapt to changing conditions
- Applications
  - Chemical systems
  - Swarm intelligence
  - Software applications (Internet, 'Genetic Computing'
  - etc

Applications

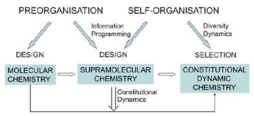
- Few current applications, many ideas
- Supramolecular Chemistry
- Computing
- Collective Construction

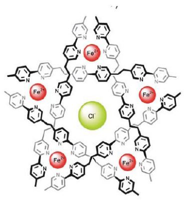
Supramolecular Chemistry

- "Supramolecular chemistry refers to the area of chemistry that focuses on the noncovalent bonding interactions of molecules."
  -Wikipedia
- "…constructing highly complex, functional chemical systems from components held together by intermolecular forces."
  -J.M. Lehn

Supramolecular Chemistry

- Information technologies
- Self-repairing polymers
- Catalysis
- Green Chemistry
- Sensors
- Medicine





J.M. Lehn

DNA Computing

- Massively parallel
- SIMD architecture
  - Can't do everyday computing, useful for combinatorial logic problems.
- Carefully constructed problems only

Wikipedia.org

Spin Computing

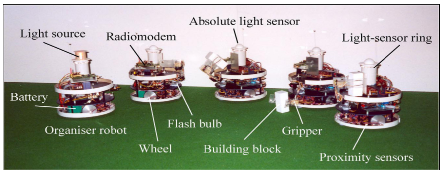
- No energy to switch states of electrons
- Applications to storage are clear
- Applications to processing less clear

Collective Construction

- Eusocial insects building structures
- Applications
  - Structures resulting from robots' collective behavior
    - No need for centralized manufacturing of consumer items
  - Structures made from the robots themselves
    - Ultimate Swiss Army knife

Collective Construction

- Simple autonomous units need only know the state of neighbors
  - Limited computing power available to the individual



Stewart et al.

Complexity Engineering

- New ways to approach problems
- All fields of engineering are affected by these ideas
- Transition period currently where emergent behavior is being accounted for rather than exploited

Discussion Points

- How comfortable are you with the idea of living around a skyscrapers built autonomously?
- Is there a limit to how far we can take collective construction?
- Do these technologies seem especially dangerous compared to nuclear and biological technologies?
- Are these technologies worth the economic risk (regarding personal manufacturing)?

References

- Stewart et al. *Modeling a Deposition Process in Collective Construction*. *Turkish Journal of Electrical Engineering & Computer Sciences* 2007.
- Dobson et al. Complex systems analysis of series of blackouts: Cascading failure, critical points, and self-organization. *Chaos* 17, 2007.
- Dobson et al. Blackout Mitigation Assessment in Power Transmission Systems. *System Sciences* 2003.
- Buchli et al. Complexity Engineering Harnessing Emergent Phenomena as Opportunities for Engineering. 2005
- Strogatz, Steven. Sync. Hyperion, New York, 2003.
- Kurzweil, Ray. The Singularity is Near. Penguin Books, New York, 2005.
- Lehn, J.M. From Supramolecular Chemistry Towards Constitutional Dynamic Chemistry and Adaptive Chemistry. *Chemical Society Reviews*. 2007.