Simon Dobson

Systems Research Group
School of Computer Science and Informatics
UCD Dublin, Belfield, Dublin 4, Ireland

http://www.ucd.ie/csi

simon.dobson@ucd.ie

http://www.simondobson.org

From adaptive systems to adaptive spaces

Dagstuhl seminar on resilient and survivable networks, infrastructures and services. July 2007

Overview

Resilience and survivability asem to be inherently system-wide concepts

- Does no good to have a resilient component if the network as a whole is fragile – and indeed the term itself may have no meaning

Adaptation helps, in a broad sense

- Change behaviour in details to account for changing conditions
- …while offering a predictable and stable quality of service
- …and so dooming engineers to perpetual under-appreciation

The argument we'll make here

- Achieving this stability requires a whole-system modeling approach
- Able to trade-off and analyse radically different issues

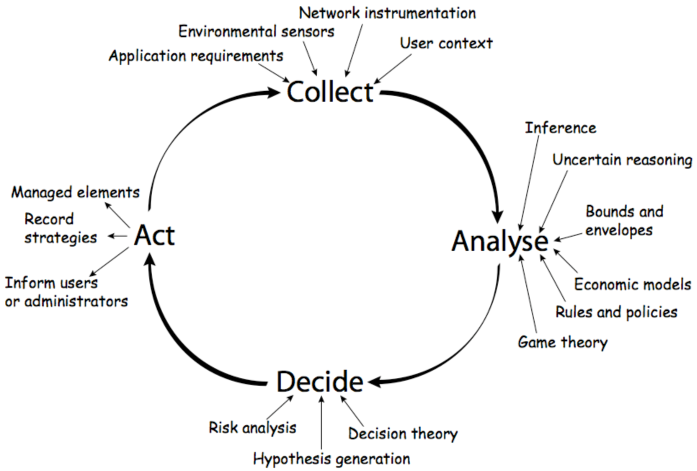
Autonomics

Autonomic is *not* the same as stable or predictable

- Getting decent feedback loops needs work
- Not all feedback is desirable

What we need

- What a system should do in response to stimuli
- A guarantee that it does indeed do this
- A way of constructing such systems compositionally
- Separate description from mechanism



From Dobson, Denazis, Fernandez, Gaiti, Gelenbe, Massacci, Nixon, Saffre, Schmidt and Zambonelli. A survey of autonomic communications. ACM Transactions on Autonomous and Adaptive Systems **1**(2). 2006.

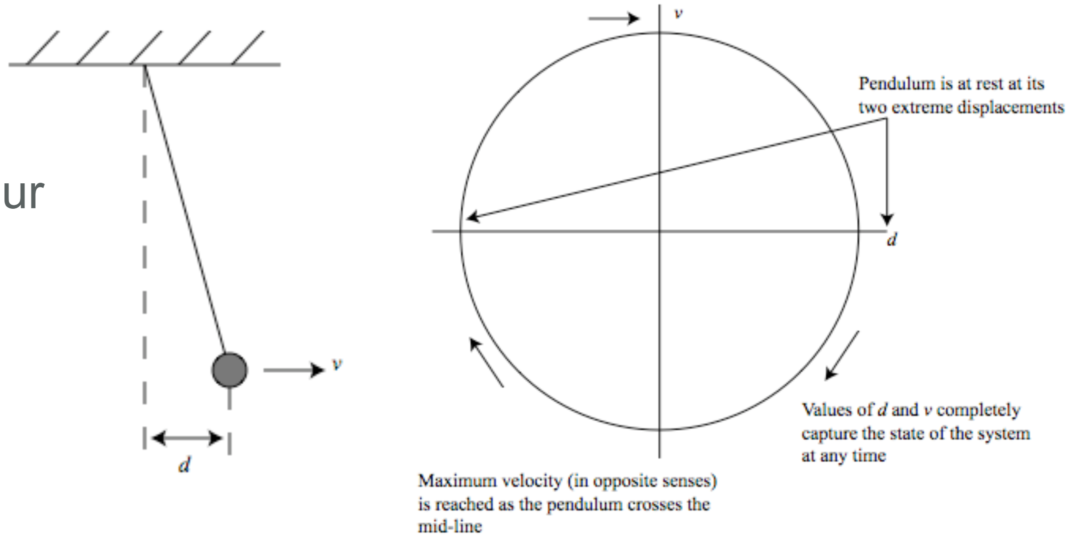
Closed-form descriptions

An adaptive system should adapt within an *envelope* of acceptable behaviours

- Adaptation is “movement” within a “space” of possibilities

This same basic description is applied to general dynamical systems, as *phase spaces*

- Obtain a closed-form description of a system’s behaviour
- Mathematically well-developed (if a little head-wrecking)



Tools and challenges

The advantage of this view is that the mathematical tools are very well-developed

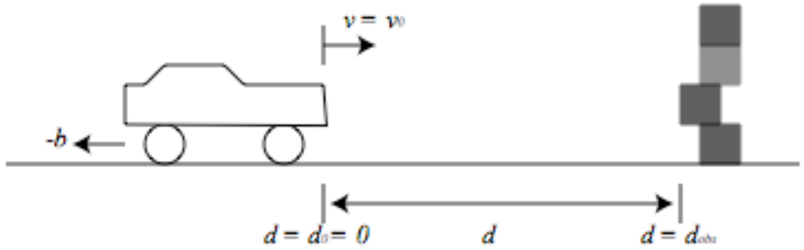
- Fields – define a quantity that varies continuously over another
- Especially *vector* fields and the associated calculus – div, curl, grad and all that
- Closely linked to differential equations, chaos, catastrophes, …
- Topological characteristics that are “desirable” in whatever sense

This has been used in, for example, coverage calculations in WSNs by Ghrist and da Silva

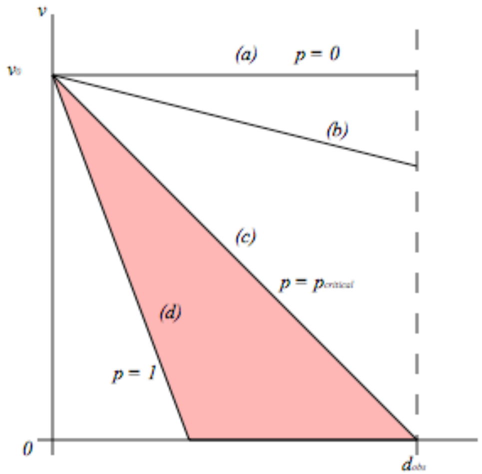
But it’s not all rosy

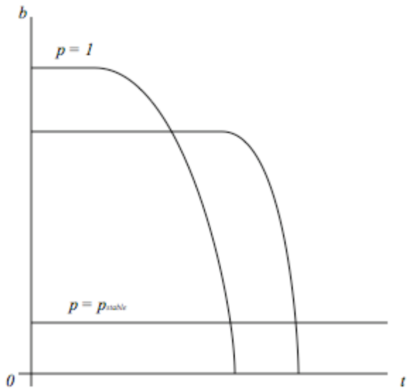
- Computers are often discrete, and it’s not clear that a lot of vector field theory applies (but it might…)
- Implies we can define adaptive spaces ahead of time, which isn’t obvious (but is advantageous if we can…)
- No necessary link from semantics to implementation – descriptive, not prescriptive (but this might not be bad…)

Initial application



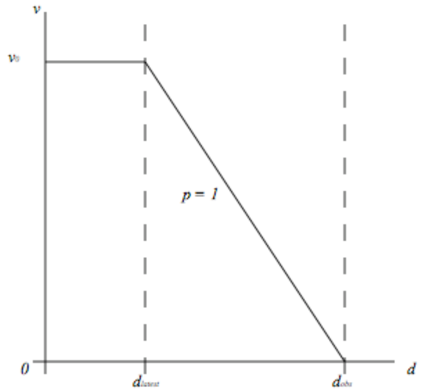
Drivers typically don't brake hard enough, or brake too hard





Heating makes brakes behaviour non-ideally

Compose these curves for a full description



Distance sensor can "add pressure" to the brake pedal to improve performance

Dobson, Bailey, Knox, Shannon and Quigley. A first approach to the closed-form specification and analysis of an autonomic control system. Proc. IEEE ICECCS. Auckland NZ. 2007.

What has this to do with resilience?

A network, and the components within it, can be described in terms of their effects on packets

- Arrival curves, delivery curves, packet loss, …
- Implications in terms of delivery, bandwidth, fairness, isochrony etc can be analysed
- Adding sensors provides finer observation

Le Boudec and Thiran. Network calculus. LNCS 2050. 2001.

So we are looking at describing these curves in a common framework to find the adaptive space of a network

- May be under-constrained, so several solutions are acceptable
- Different trade-offs represented by different regions of the multi-dimensional space

Modeling resilience

Construct the adaptive space of the network and any software running on it

- Capture possible contextual constraints as “dimensions” of the space
- Responses form the “co-dimensions”
- Characterise the properties we want to maintain/avoid according to the topology of the space

Different strategies for addressing problems modeled as different dynamics for moving around the space

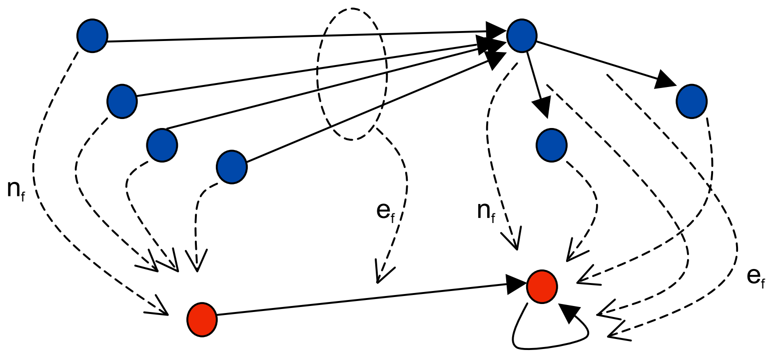
- Convergence, stability, …

Does this work? Don’t know yet, but there are reasons to hope so :-)

Overall goal

To understand the adaptive space of a system, and ensure that its movement within it is consistent with respect to its intended external semantics

- Characterise strategies in terms of how they move the system within its adaptive space
- Ensure we select (one of the) appropriate strategies at the right time
- "Fibre" contexts over the behaviours (strategies) they select



Ye, Clear and Dobson. Towards a formal semantics of pervasive adaptive systems. Accepted for The Computer Journal.

Ideally like an end-to-end model of all these aspects

Conclusion

This problem of whole-system modeling, analysis and understanding that is currently absorbing a lot of our attention

Treat resilience, stability and adaptivity within a framework that'll support proper analysis

- Guarantees of behaviour generate confidence

Long-term

- Improve both analysis and development of predictably-adaptive systems
- Incorporate semantically well-founded constructions into programming tools