An Engineer Imagines. Again. by Christos Ellinas

Status Quo

Everything is connected with everything else. This may sound rather maximal but is it really? You, reader, may well be reading this article on a website while enjoying a Spanish orange on a beautiful Hawaiian beach. The WWW, our supply chains and our transportation infrastructure are beautiful examples of how engineers systematically increase coupling to achieve more with less. Alas, heightened connectivity comes with a cost. A falling tree can leave 50 million people without power; a small fire can *risk* bringing down the world's biggest car manufacturer and the collapse of one financial institute can endanger the entire economic *system.*

But why should you care, after all it's probably some politician's fault. I hope some figures will make it clear – the annual cost of such power outages is estimated between 88-188 billion USD; similarly the estimated cost of the recession resides between 6-8 trillion USD – both in the USA alone. These are extraordinary losses in terms of resources and we are in desperate need of imaginative engineers to shield our society from such asymmetrical cascades. But where do such cascades arise and why do they occur in the first place? Can we shield ourselves, or even better, eliminate their occurrence completely?

Knowledge

Recent *scientific* research has revealed an important property of these systems – their *interconnections*, as a result of their increased coupling, is not randomly distributed. This may appear as common sense to a layman (after all you are not "connected" to random people per se) but the greater implication is that connectivity may indeed be more important than their composing *discrete* elements. Insight on the causal mechanism of their asymmetric distribution has served as the foundation of theorising with respect to their robust-yet-fragile nature. An entire scientific society has recently emerged, after a series of such discoveries, in an attempt to better understand these naturally-occurring phenomena as they appear to be at the heart of these questions. Nevertheless, our view within this domain is opaque at best and we urgently need answers in order to readily improve our designs.

But how has the *engineering* society responded to this influx of scientific knowledge? Engineering traditionally provides the means of exploiting natural phenomena – let it be a process, a methodology or an artefact – to achieve a desired effect in an attempt to realise a purpose. However, traditional engineering routinely *divides* a problem to a number of sub-problems until they become simple enough to tackle. This logical division represents the human perception of a problem; unfortunately such linear representation contradicts the inherent complexity of the systems that we desire, often resulting in unintended *emergent* properties such as proneness to disproportionate cascades of failure.

OUR CONTRIBUTION AND VISION

Exercising good engineering design necessitates harvesting useful complexity to deliver increased functionality with fewer resources while limiting the inherent risk. Yet we still apply tools largely tailored to discrete deconstructions of systems, ignoring their true complexity and concluding to a potentially false sense of confidence, further enlarging our risk exposure. Our research focuses in responding to this lack of *holistic* tools in structuring and managing complex engineering projects by focusing on the way their components *interact*. By showing that both natural and man-made systems are largely empowered by their *interconnectivity*, we are developing tools that will map the ability of the former to adapt to ever-changing conditions in order to increase robustness. Such reliance implies an increased probability of delivering complex projects per agreed requirements, and thus, certainty on resource expenditure. Acknowledgment of the social aspect is also fundamental – after all we are all, by design, risk-averse creatures filled with cognitive biases which limit our capacity for rational decision making. As time for diffusing the research deliverables to the industry is vital, and in the spirit of the engineering doctorate programme, real data provided by our industrial collaborators form the cornerstone of our research. This forces the development of tools that deal with imperfect, fuzzy data that engineers routinely deal with rather than the perfect, artificially-constructed data that theoretical research utilises.

Grande projects such as the BRAIN project, and dare I say, global warming, are crucial for our advancement – these are challenges that all of us need to be actively engaged with. Failure to do so may well lead to technological stagnation and limit our chances of survival in an environment which *we* have turned against us. It is an opportunity for scientist and engineers to engage in a constructive dialogue. We cannot afford being limited to the theoretical realm (science) or keep designing systems that we do not understand (traditional engineering) as the impact of failure will resonate much harder. The combination of holistic approaches and industrial know-how will prove vital in our success as we tackle our biggest challenge yet, both as engineers *and* human beings.