An Information-Theoretic Approach to Resilience Assessment

レジリエンス性評価のための情報理論的アプローチ

*Jonathan A. Poli and Kazuyuki Demachi

[1]University of Tokyo Department of Nuclear Engineering and Management

Abstract: This study has two purposes. The first purpose is to propose new metric for indicating resilience based on uncertainty in communications between system and Decision-Maker. The second purpose is to develop an approach to implementing resilience based on the new metric. **Keywords:** resilience, information entropy, network

Resilient systems acquire information regarding their external and internal environments and decide what feedback to employ. Invariably, this process involves communication between the system and the Decision-Maker (DM), the latter responsible for deciding what feedback to employ. The system codes the message onto a group of information sources, each one delivering a one unique piece of information and each source corresponding to a unique sub-channel (Figure 1A). The aggregate of sub-channels serve as the main channel transmitting messages between the system and DM. The "noise" serves to prevent sub-channels from communicating their piece of information (Figure 1A). The more sub-channels lost, the more possible messages that must be considered, the more uncertainty. The uncertainty can be measured by information entropy; a measure of the uncertainty from the receiver's perspective in selecting the actual message from a set of possible messages [1]. Information entropy is an indicator of how effectively the system is communicating with the DM. A resilient system, thus, maintains communication by limiting the increase in uncertainty as sub-channels are lost, and recovers rapidly if it happens to be in a state of high uncertainty (Figure 1B). *The convexity of information entropy curve as a function of missing sub-channels serves as the proposed indicator of system resilience.*

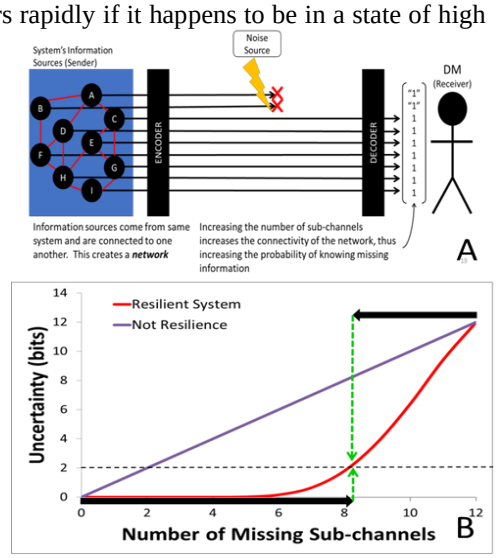

Figure 1: (A) **Schematic of communication channel (top) and the effect of noise on the channel. (B) Plot of uncertainty (information entropy) as a function of increasing number of lost sub-channels.**

Based on the convex, response, the goal is to incorporate such behavior in the communicating process. Given that all of the sub-channels are a part of the same system, it is reasonable to infer that information sources are linked to one another. Connecting all related information sources results in a network where the information regarding a missing sub-channel can be inferred from the information output of linked sub-channels. More importantly, network connectivity follows convex behavior [2]. Incorporating the network characteristics is the approach to attain convexity and may provide an avenue towards engineering resilience. A methodology was developed to measure information entropy and a model was used to assess the network hypothesis. Results are discussed and a case study applying this method to the Isolation Condenser system of Fukushima Daiichi Unit 1 serves as an illustrative example.

References

[1] Shannon, C. E. (1948). A Mathematical Theory of Communication. *The Bell System Technical Journal*, *27*, 379–423.

[2] Bettstetter, C. (2004). On the connectivity of ad hoc networks. *The Computer Journal*, *47*(4), 432–447.