Numerical Safety Analysis of Complex Supply-Chain Systems Integrating Functional Resonance Analysis Method and Cellular Automaton

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FRAM is a practical way to analyze Socio-Technical Systems based on the systemic perspective: their global behavior of those systems come from variabilities and/or fluctuations of the individual functions as well as from their interactions among those. However, FRAM has typically functioned as a qualitative method; a systematic way of using FRAM analysis has not yet been established. This is mainly due to the ambiguous definition of entities such as “variabilities”, “propagations”, and “their interactions”. To overcome this problem, we propose an extended model of FRAM: we integrate FRAM and Fuzzy CREAM, i.e., an extended model of CREAM (Hollnagel 98), with fuzzy reasoning, to parametrize above entities quantitatively. This enables to define variabilities of working environment and functions as changes of CPC: Common Performance Condition score and PAF: Probability of Action Failure, respectively. Also, we implement the method based on an analogy existing between interactions among functions of FRAM and among the emerging complex behaviors among elements according to the framework of cellular automaton, which enables the analysis of dynamic behaviors of complex systems. Then, a case study with the proposed method will be carried out to analyze a behavior of a steel production line: we simulate how variabilities existing locally in the system propagate to the rest of the system and how those influence a global behavior of it, as well as how the remedies to those are valid to recover from fluctuated system status to a novel stable state realizing the so-called “Safety-II” characteristics of resilience systems. The result show that the behavior of the system depends on when the variabilities become active. Moreover, the result suggests that the global behavior of Socio-Technical Systems depends on a specific context that is active at the moment. In the end, we present how the proposed method will be utilized to design complex Socio-Technical Systems such as supply chains, airliners, and nuclear power plants.