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Human-System Co-Creative Design of Resilience

Tetsuo Sawaragi*

** Department of Mechanical Engineering and Science, Kyoto University, Kyoto, Japan.*
(Tel : +81-75-383-3581; e-mail: sawaragi@me.kyoto-u.ac.jp)

Abstract: This is a tutorial paper on Human-System Co-Creative Risk Management for Establishing Resilience against the Disturbances. This is the summary of the academia-industries collaborative project organized under the Iron and Steel Institute of Japan (ISIJ) from 2012 to 2015 on the topic of Human-System Co-Creative Risk Management for Establishing Resilience against the Disturbances. In this project, at first the sources of the performance variability to encounter in steel industries were identified, then systematical approaches to establishing resilient production and operation systems are discussed. The approaches are roughly divided into the two approaches; one is a systems approach to resilience and the other one is a human behavioral analysis approach. The former approach is to seek for a novel optimization technique for the complicated task scheduling in steel companies. The second approach is to seek for a human-optimization joint collaboration. This paper summarizes these and describes some of the on-going research topics to tackle with the variability caused by diverse sources of fluctuations during production planning and operation.

Keywords: Resilience, steel production, ecological interface design, human reliability analysis, supply chain management, serious game.

1. Introduction

Today, the scene of manufacturing in Japan needs increased flexibility to diverse "fluctuations," which are beyond what were previously expected due to market transformation, overseas expansion of businesses, and changes in the energy and economic environments. Additionally, fluctuations that are resulted from decreased product quality due to the retirement of a large number of skilled workers and the dysfunctions of decrepit manufacturing equipment have caused serious problems. To deal with such various fluctuations, co-creation by human beings and systems is indispensable. To do this, it is needed to establish a systemization technology that 1) analyzes vulnerability that systems have in the event of unexpected diseases and 2) conducts stress tests, which are aimed at prevention of severe accidents, in a more expansive manner not only on hardware but also on the entire activity conducted by human beings, machines, and organizations.

In this context, the author and colleagues have advanced a study of "Risk Management with Human-Machine System Co-Creation to achieve resistance toward fluctuation" for three years from March 2012. This project was adopted as a part of the Action Plan for the Reconstruction after the Great East Japan Earthquake, which was supported by The Iron and Steel Institute of Japan. This paper summarizes the research activities in this project and offers perspective and methodology to design systems with restoring force against fluctuation by the co-creation by human beings and systems, with a focus on the concept of "resilience," which is what we have tried to share across the research project members.

In this thematic session, a number of papers on the methodologies for the analysis and design of resilient systems are presented. Especially we put emphasis on the *socio-technical systems* and investigate into the difficulties that are brought about out of the complicated interactions among the human, technologies and organizational factors. With respect to *resilience engineering*, it looks for ways to enhance the ability at all levels of organizations to create processes that are robust yet flexible, to monitor and revise risk models, and to use resources proactively in the face of disruptions or ongoing production and economic pressures. Wherein, failures do not stand for a breakdown or malfunctioning of normal system functions, but rather represent the converse of the adaptations necessary to cope with the real world complexity. Individuals and organizations must always adjust their performance to the current conditions and success has been ascribed to the ability of groups, individuals, and organizations to anticipate the changing shape of risk before damage occurs.

2. What is the Resilience?

The concept of "resilience" has received much attention rather than "robustness," which is a traditional concept of strength. Resilience means "having a strength accompanied by suppleness, which does not results in a break up, similar to the trunks of willow trees." Although the term of "resilience" was originally a term of physics, since 1970s this term was proposed and started to be used in the field of psychology as a term representing a concept of psychological homeostasis. Here resilience meant 1) the ability to maintain psychological health, or 2) the ability to

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recover psychologically healthy state when temporarily suffering from psychological maladjustment. In 1973, C.S. Holling, a Canadian ecologist also proposed to use "resilience" in the field of social science due to that ecological systems had ability to restore the original state upon environmental changes, which is similar to the homeostasis that living organisms have (Holling, 1973). He offered two features regarding the concept of resilience in the field of social science. The one is that the resilience is characterized with "socio-ecological system," which refers to the relationship between human beings and nature, and the other is that "resilience" toward changes and/or fluctuations is an essential property that every system needs to have. The definition of the resilience offered by Holling put an emphasis on its aspects of unpredictable responsiveness to external disturbances as well as self-organized phenomena, which seemed to be close to the definition of complex adaptive systems. But subsequently, the concept of resilience has become increasingly common as a property that societies, cities, or communities need to have.

Today, the concept of resilience is used in diverse fields. In every field, the term is commonly used to represent "ability to adapt to a changing environment and to survive in a flexible manner despite facing difficulties." Furthermore, the concept of resilience has received increased attention as abilities for risk-aversion and crisis control that are needed in every level of societies, from individuals to entities such as businesses and administrative organizations. In such a context, the concept of "resilient engineering" was proposed by E. Hollnagel et al. (2012). In Japan, Prof. M. Kitamura detailed about the concept of resilient engineering (Kitamura, 2015).

By the way, the concept of resilience reminds the author the concept of "*Shinayaka* Systems Approach" proposed in the field of system engineering from 1970s to 1980s. The following is an excerpt from a book wrote by Prof. Yoshikazu Sawaragi, who was a professor emeritus at Kyoto University (Sawaragi, et al., 1992).

"Traditional systems approaches had been efficient for well-defined systems because such approaches were a kind of gathering of hardware, like the Apollo program. On the other hand, the *Shinayaka* Systems Approach is a methodology having adequate degree of softness and robustness. This concept was generated by learning from biological systems as I found a great appeal in that living things had a feature that they had not only a great flexibility and adaptivity, but also robustness, namely an unflagging toughness.' Although the traditional approaches systems were systems organized from outside, the *Shinayaka* Systems Approach is a self-organized system. This self-organizing phenomenon, which is also known as a *synergetic* phenomenon, is great one we can observe in common to both of living and non-living objects. We have to focus on it and devote every effort to the realization of this concept."

This concept proposed by Prof. Y. Sawaragi seems to be stemmed from his experience on phenomenon analysis of self-excited oscillation in dynamical systems. It is likely to be based on the self-organization phenomena, which are created by generating some instability in an in non-linear system having feedbacks transiently under a certain condition, and selecting a steady state among possible several steady states. Such an interesting characteristic of non-linear systems, in which the results can be either desired or undesired, is a common feature of the current discussion around the resilience.

3. SOCIO-TECHNICAL SYSTEMS AS LARGE-SCALE COMPLEX SYSTEMS

The "socio-technical systems" is now studied in more diversified fields. Previously, such a system was studied in fields from a field that investigated changes in human work resulted from the introduction of information technologies. Subsequently, it has become to be studied in a field that discusses ideal application of information technologies not only at manufacturing sites but also at every sites of business, and the field studying the Computer–Supported Collaborative Work (CSCW) based on observation of the actual usage of such new technologies. This article summarizes the socio-technical systems in the field of "cognitive engineering" that was proposed by E. Hollnagel and D.D. Woods et al., putting a strong focus on the trends in which such systems are utilized for analyses of accidents caused by organizational factors as well as in safety design, within interacting systems (Hollnagel and Woods, 2005).

At working sites, such as production sites and medical sites, workers have been experiencing drastic changes in their work, resulted from the introduction of new equipment and systems, as well as ever-changing client' needs. Such changes in work are generated from the interaction between the site and the surrounding environment and/or entity. Namely, entities have multiple communities of practice, in which artifact objects such as procedures or mechanical systems that have been developed omitting the communities' practice may be rejected by the communities or may disturb the communities' activities, which sometimes can lead to severe accidents.

On the other hand, safety culture is constituted of three phases: the first is the technical phase, the second is the human error phase, and the third is the socio-technical phase. Safety analysis methodologies needed for each phase has undergone a transition. Especially, currently safety assessment in the third, socio-technical phase is needed as a lot of incidents are induced by the interaction among factors of technology, individual, society, management, and organization, as well as the complex and dynamic aspects of these factors. In that phase, recently a new accident pattern, *systemic accident*, has arisen, in which accidents are not directly caused by a major deviation from safety procedures, but by amplification and resonant interaction of accumulated performance variability in an individual work procedure. Accordingly, reliability assessment methodologies have to be advanced from conventional ones to new ones. The conventional reliability assessment has calculated a probability of a series of event sequences triggered by the initiating event based on the evaluated probabilities of