

## SPECIAL ISSUE ON IMMUNITY-BASED SYSTEMS: SYSTEMS SCIENCES FOR ROBUST AND RESILIENT ENGINEERING

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Received November 2013

In the course of studying complex systems inspired by biological systems (such as the immune system) and attempting to mimic the robustness, resilience, and adaptation of these systems, several fundamental sciences such as systems sciences, dynamic systems, game theory, and network science have attracted considerable attention. Immune systems, in particular, have led to the development of distributed, adaptive, and self-maintenance systems (adaptation to the internal *self* as well as to the external *environment*), which can be used in information systems whose survival is critical for reducing the damages caused by large-scale natural disasters.

After the recent gigantic natural disasters, we have realized that resilient systems should deal with various situations including the following:

- **Unavailable Information:** Most information that is readily available for daily use may not be available because of the chaotic situations caused by a natural disaster.
- **Unavailable Immediate Response:** Most situations are assumed for routine tasks and may not be valid because of the drastic environmental changes caused by the disaster, implying that prompt organized rescues are unavailable.
- **Unavailable Infrastructure:** Although infrastructure including transportation, communication, and information systems is critical for the survival of the people, it is not only unavailable but is also difficult to fix and recover after the disaster.

Coping with the abovementioned situations is considerably difficult and challenging for a single field of science and technology, and hence many fields should be involved and should be studied both on a long-term and on a short-term basis. This special issue, aiming at bringing together researchers working across fields such as sensor networks, information security and systems sciences, calls for papers on Systems Sciences and Technologies for Robust and Resilient Engineering based on the features of the immune systems: robustness, resilience and adaptation.

For innovations such as achieving robustness while seeking optimization, conventional methods may be enhanced with a completely distinct method. Angeline Vijula Dhanraj and Devarajan Nanjundappan used the *particle swarm* optimization for designing a PI controller in the multi-input–multi-output (MIMO) process. In contrast to a conventional optimization approach, Masahiro Tokumitsu proposed adaptive strategies, with which he claimed that a system would exhibit a high performance on average in a dynamic environment. A dynamic environment imposes plays with many types of adversaries. An optimized but fixed strategy can exhibit the best performance with a specific type of adversary but may not perform well on average with many other types of adversaries. He also posed some open problems for the development of the concept of adaptive strategies.

An important principle inspired by the immune system is *self/nonself discrimination*. Tao Shang, Hengli Pei, and Jianwei Liu introduced a lattice theory to construct a secure signature scheme based on *self/nonself discrimination*. They proposed a scheme with a stronger unforgeability for the natural property of lattices than traditional signature schemes. An ad-hoc network also plays a crucial role in establishing resilient communications that recover even when base stations are destructed. Ajay Guleria, Narottam Chand, and Lalit Kumar proposed a new data dissemination scheduling strategy for on-demand broadcasting of information from a roadside unit to support the differentiated levels of services in vehicular ad-hoc networks. Although their goal was to increase road safety, the model can lead to resilient networking. We know that chaotic conditions after a disaster may cause imbalances in the inventory level at each storage location or shelter. Nur Budi Mulyono developed a resilient logistics method to ensure an even level of inventory among shelters, introducing a new model based on probabilistic cellular automata.

The immune system can also inspire innovative modelling. One such innovation is to remove the formal distinction between data and a function on cellular automata. Kouji Harada devised a model in which a function and the corresponding data determine each other in contrast to conventional models where a function determines data as an output. The model also demonstrates that the mutation allows a transition between dynamical orbits and creates a meta-attractor attracting most orbits. Another aspect of the immune system is that it arms itself with a *double-edged sword*. I have also reported a self-repairing network, which is a probabilistic cellular automaton, to deal with the problem of cleaning a contaminated network by mutual-copying and self-copying. Repairing by copying among agents is the *double-edged sword* that can spread contamination unless it is appropriately used. We focused on dynamics rather than the static aspects by incorporating several phase diagrams to visualize the transient states.

In an attempt to frame the immune system of humans and the Earth, we investigate asymmetric interactions between humans and the Earth (environmental problems such as global warming, climate change, and pollution) and those between the Earth and humans (natural disasters such as earthquakes and tsunamis). A new perspective for the reconciliation of humans and nature, as obtained from the immune system, may be shaped around the concepts of diversity, adaptation, and resilience. This special issue is just a small step toward resilient systems; however, adaptive systems in diversified domains, techniques, approaches, and modelling may have been already recognized.

We regret that many important papers could not be included in this special issue; however, we presume that many similar special issues, books, and projects will emerge from many fields hopefully before the next human-threatening disaster. We are grateful to all the reviewers for the papers included in this special issue and for those not included in this special issue. Special thanks go to the Executive Editor of IJICIC, Prof. Yan Shi, who supported the entire publication process, including reviewing and editing, for this special issue.