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Modelling self-adaptive expert systems for ageing Infrastructure asset management using plausible petri nets

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Most existing infrastructures continue to grow in size and complexity, but also to age as a consequence of increasing demand of use. Accordingly, increasingly greater safety and economic challenges are coming into play in relation to the management of those infrastructures. Resilience engineering is nowadays getting higher attention as a key enabler to propitiate a paradigm shift in infrastructure management, as a way to make infrastructures capable of survive perturbations by adaptation and evolution by anticipation of changes in internal (and also environmental) conditions.
In parallel, developed countries are facing the onset of a new industrial revolution due to the rapid development of technologies including artificial intelligence, sensing and robotics. Infrastructures and the built environment will certainly be part of this revolution due to their massive impact on the economy and society, and the low cost of these new technologies in relation to the cost of the infrastructure. As a result, the amount of real-time data and information coming from monitored infrastructures is expected to increase exponentially over the coming decades. This information has the potential to reduce by billions the national expenditure on infrastructure asset management. Henceforth, there is a clear need to exploit the full potential of such infrastructure monitoring data by combining state-of the art artificial intelligent approaches with physics-based models for infrastructure operation and ageing, as a paradigm shift on what is typically known as Smart Infrastructure.

This talk focuses on the application of a Petri Net-based formalism to model self-adaptive expert systems, which are understood as expert systems with the ability to sequentially learn from data. To this end, a novel computational framework is proposed by combining the Bayesian learning principles with the Plausible Petri nets (PPNs) methodology, first developed in M. Chiachío et al. [Proceedings of the Future Technologies Conference, San Francisco, (2016), pp. 165-172]. In this research, the PPNs are used for their efficiency to jointly consider the dynamics of discrete event-driven systems together with uncertain knowledge representation about the system state, which offers the possibility of integrating in a natural way continuous and discrete dynamics in a single net model under consideration of uncertainty. This fact makes them useful for analysing hybrid systems with interaction of diverse sources of information, like in expert systems. The talk will also give the conditions whereby the Bayesian updating becomes a particular case of a more general basic operation within the PPN execution semantics, which allows the uncertain knowledge about the system state being updated from data in a rigorous manner. The approach is demonstrated in a self-adaptive expert system for railway track inspection management taken as case study using published data taken from a laboratory simulation of train loading and tamping on ballast, carried out at the Nottingham Railway Test Facility, University of Nottingham. The numerical results reveal how the uncertain information from measurements and Bayesian algorithms can be processed, transferred, stored, and integrated with discrete- event inspection activities for optimal nonlinear control operations at system level.