Guest Editorial

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Guest Editorial: Value of Information (VoI) in reliability and risk assessment

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Reliability analysis and risk assessment are based on structured frameworks to organize the Knowledge, Information and Data (KID) available on Systems, Structures and Components (SSCs).[1] The outcomes of the evaluations are used to inform decisions on SSCs design, operation, maintenance. In relation to this, in this Special Issue, the mathematical framework of Value of Information (VoI) is considered in view of the support that it can provide in evaluating the investments for gathering KID in comparison to the benefits for confident reliability analysis and risk assessment, and the following decision making.

The concept of VoI has been introduced in the 60's in the field of statistical decision theory and for optimal decision-making.[2] It is based on both utility theory and Bayesian probability theory.[3] In layman's terms, VoI aims at quantifying the expected improvement in the random outcome of a decision problem, which may be achieved from gaining an additional piece of information on the problem prior to the decision. The more useful the piece of information, the more potential for improvement in the decision outcome. Then, the VoI framework constitutes a powerful tool to rationally organize information collection and exploitation for reliability analysis and risk assessment.

In this collection of four research papers, authors have addressed some of the open issues and challenges for the application of the VoI framework in the practice of reliability analysis and risk assessment, such as:

- Life-cycle management of degrading engineering SSCs based on the gathered KID;
- Methods of optimization for sequential decision making (such as optimal inspections planning);
- Computational complexity of the VoI evaluation.

The paper by Chaochao Lin and Matteo Pozzi is a methodological study, which investigates the topological importance of the various components that constitute a system with structural redundancy. It especially focuses on the priority order that should be given to the inspection of the different components in that particular arrangement. The purpose of the analysis is to identify the policies that lead to minimal life-cycle cost. The problem is cast in a Partially Observable Markov Decision Process (POMDP) framework. VoI is computed through approximate resolution schemes and computational complexity is addressed. It is shown that inspection priorities depend on the economic discount factor of the life-cycle cost problem, on the inspection precision and on repair costs.

The paper by Guang Zou, Kian Banisoleiman and Arturo González addresses the example of a marine offshore structure which is prone to crack growth and eventually fatigue failure. Various inspection and maintenance strategies are compared under diverse settings, defined through multiples values for the ratio of repair to failure costs or for the inspection precisions. Computation of VoI is carried out when comparing optimal strategies involving inspection to strategies that do not. It is shown that depending on the particular setting of the decision problem, inspection may or may not be profitable and that the answer to the inspection question should be provided prior to investing in costly inspection campaigns on offshore structures.

The paper by Jorge Mendoza, Jacopo Paglia, Jo Eidsvik and Jochen Khler discusses the example of a mooring system on an offshore structure, which is subject to corrosion degradation and may fail when some of its constituting elements have failed. The corrosion process is not uniform on the whole structure but there is significant correlation as elements degrade in a similar environment. A Bayesian Network is used to model the dependencies between the different elements and update the estimation of the structure condition when in-situ inspections are conducted. VoI computation is, then, conducted and used to rank different inspection alternatives.

The paper by Seyed Motjaba Hoseyni, Francesco Di Maio and Enrico Zio deals with optimal sensor positioning on a pressurized vessel which may experience failure due to creep. The vessel is modelled as a random field of varying thickness and presents areas with higher thickness uncertainty, especially around welding lines. Simulation is carried out and sensors are sequentially positioned using a greedy optimization scheme in areas where VoI computations identifies that there is much to be gained from uncertainty reduction. Comparison is made between optimally positioned sensors and standard recommendations, showing that by optimization the same level of safety can be achieved with fewer sensors overall.

The contributions in this Special Issue show that VoI can offer a powerful framework to support reliability analysis and risk assessment, and be a key contributor to cost-effective decisions for achieving desired reliability and safety performances.

Some challenges still need to be addressed to foster VoI use in the practice, such as:

- Proper modelling of prior knowledge (e.g. behaviour of the degradation process, Gaussian fields for spatially distributed problems, etc.);[4]
- Proper modelling of utility/cost functions, as well as action alternatives, in the VoI-based decision process;[5]
- Enabling incremental learning in the Bayesian updating mechanism at the basis of the VoI calculation, to allow integrating new and heterogeneous KID from any source;[6]
- Computational complexity difficulties of VoI calculations, especially in problems where a sequential decision problem is to be solved in a time-varying context, or in problems related with infinite-horizon decision making for online sensing in spatio-temporal systems.[7]

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