The 8th European Congress on Computational Methods in Applied Sciences and Engineering
ECCOMAS Congress 2022
5-9 June 2022, Oslo, Norway

Bridging POMDPs and Bayesian decision making for robust maintenance planning for railway systems

Giacomo Arcieri*[1], Cyprien Hoelzl[1], Oliver Schwery[2] and Eleni Chatzi[1]

[1] Institute of Structural Engineering, ETH Zürich, 8093 Zürich, Switzerland
giacomo.arcieri@ibk.baug.ethz.ch, hoelzl@ibk.baug.ethz.ch, chatzi@ibk.baug.ethz.ch
[2] Strategic Asset Management, Swiss Federal Railways SBB, 3000 Bern, Switzerland
oliver.schwery@sbb.ch

Keywords: *Partially observable Markov decision processes, Bayesian inference, Optimal maintenance planning, Model uncertainty, Hidden Markov models, Dynamic Programming*

Structural Health Monitoring (SHM) exploits tools to support maintenance planning in engineering infrastructures. Monitoring serves for obtaining indicators of structural condition and for updating and refining models of operating engineered systems. This extracted information can be further combined with quantitative methods for supporting decision on optimal operation and maintenance planning. Partially Observable Markov Decision Processes (POMDPs) offer a unified framework to solve the underlying sequential decision making problem. However, two issues heavily undermine POMDP solutions. First, the recovery of i) a transition model that adequately describes the evolution of condition under deterioration or corrective action, and ii) of the uncertain observation process parameters from available data is far from trivial. Consequently, these models are often (partially) guessed. Moreover, the adopted models do not typically account for parameter uncertainty, leading to solutions which are unrealistically confident and unlikely to be deployed for real-world challenges. In this work, we address both aforementioned issues. We estimate transition matrices and observation model parameters via Markov Chain Monte Carlo (MCMC) sampling of a Hidden Markov Model (HMM) conditioned on actions. The MCMC inference recovers full distributions of all plausible values of the parameters under the available data. We then solve the POMDP problem by exploiting the inferred distributions to derive solutions which are robust to parameter uncertainty. We showcase the application of these methods to real-world data by solving the problem of railway maintenance planning on the basis of “fractal values” indicators.

REFERENCES

[1] K.G. Papakonstantinou, C.P. Andriotis and M. Shinozuka, POMDP and MOMDP solutions for structural life-cycle cost minimization under partial and mixed observability. *Structure and Infrastructure Engineering*. Vol. **14(7)**, pp. 869–882, 2018.

[2] K.G. Papakonstantinou and M. Shinozuka, Planning structural inspection and maintenance policies via dynamic programming and Markov processes. Part II: POMDP implementation. *Reliability Engineering & System Safety*. Vol. **130**, pp. 214-224, 2014.