System reliability upper bound assessment for health-aware control of complex systems

Jean C. Salazar
Universitat Politècnica de Catalunya
jean.salazar@upc.edu

Ramon Sarrate
Universitat Politècnica de Catalunya
ramon.sarrate@upc.edu

Fatiha Nejjari
Universitat Politècnica de Catalunya
fatiha.nejjari@upc.edu

phmsociety

Fourth European Conference of Prognostics and Health Management Society
3-6 July 2018, Utrecht, The Netherlands

Student Poster

Research Objective

This work investigates the possibility of using an approximate computation of the system reliability into a HAC scheme. Specifically, an upper bound of the system reliability will be computed in order to overcome the computational problem of determining the exact system reliability of a complex system and its integration into a health-aware control strategy [1].

Expected Contributions

- A HAC scheme for complex systems based on the system reliability upper bound computation.
- A reduction of the system reliability computation cost by using the upper bound approximation.

Research Details

MPC scheme tuning methodology

1. Enumerate the minimal path sets $\boldsymbol{P}_j$
2. Compute the structure function

$$\Phi_p(\mathbf{X}) = 1 - \prod_{j=1}^{s}\left(1 - \prod_{i\in \boldsymbol{P}_j} X_i\right)$$

3. Compute the system reliability upper bound

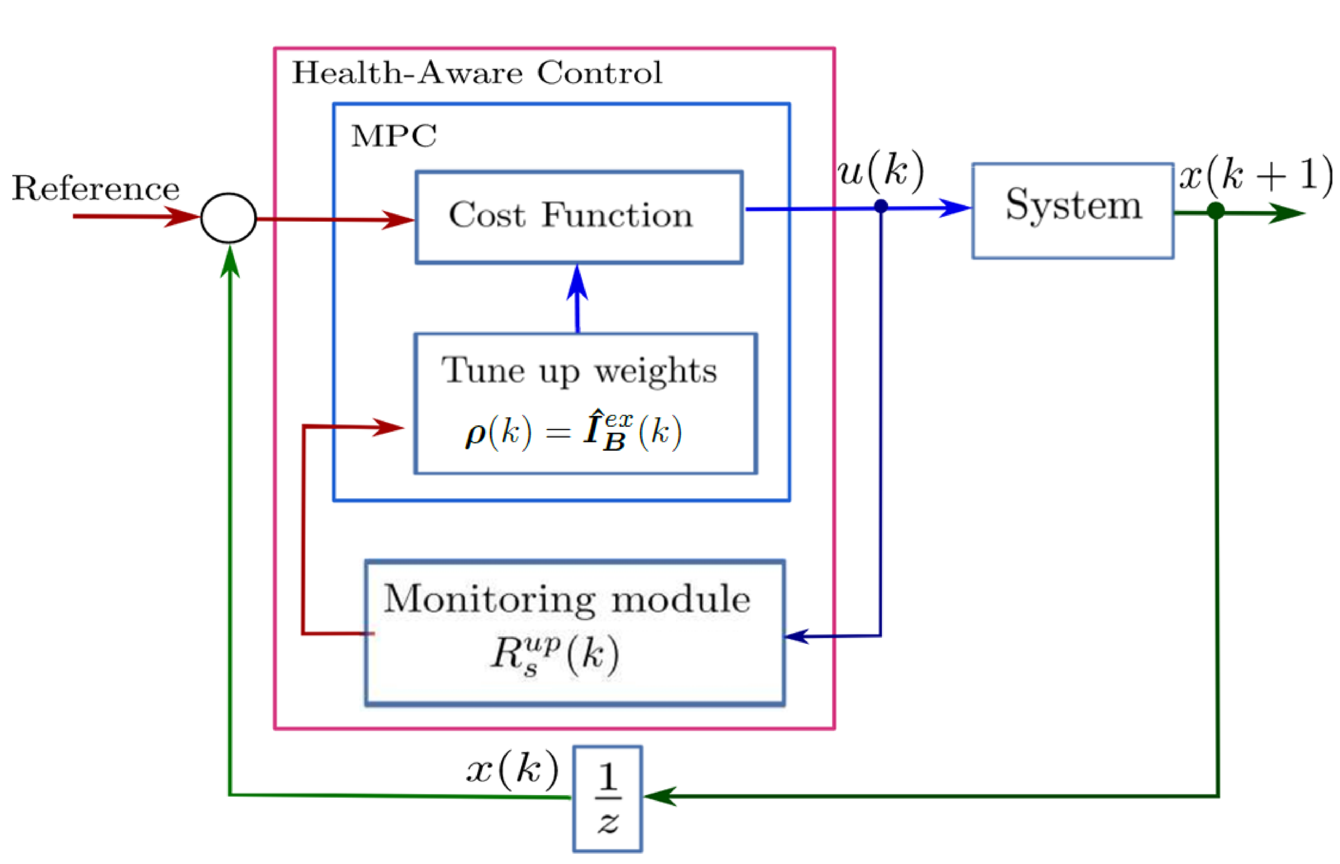
$$R_s^{up} = 1 - \prod_{j=1}^{s}\left(1 - \prod_{i\in \boldsymbol{P}_j} R_i\right)$$

4. Compute the components reliability

$$R_i(t) = e^{-\int_0^t \lambda_i(v)dv} \qquad \lambda_i(t) = \lambda_i^0\left(1 + \beta_i \int_0^t |u_i(v)|dv\right)$$

5. Compute the MPC weights based on a normalized component Birnbaum's measure

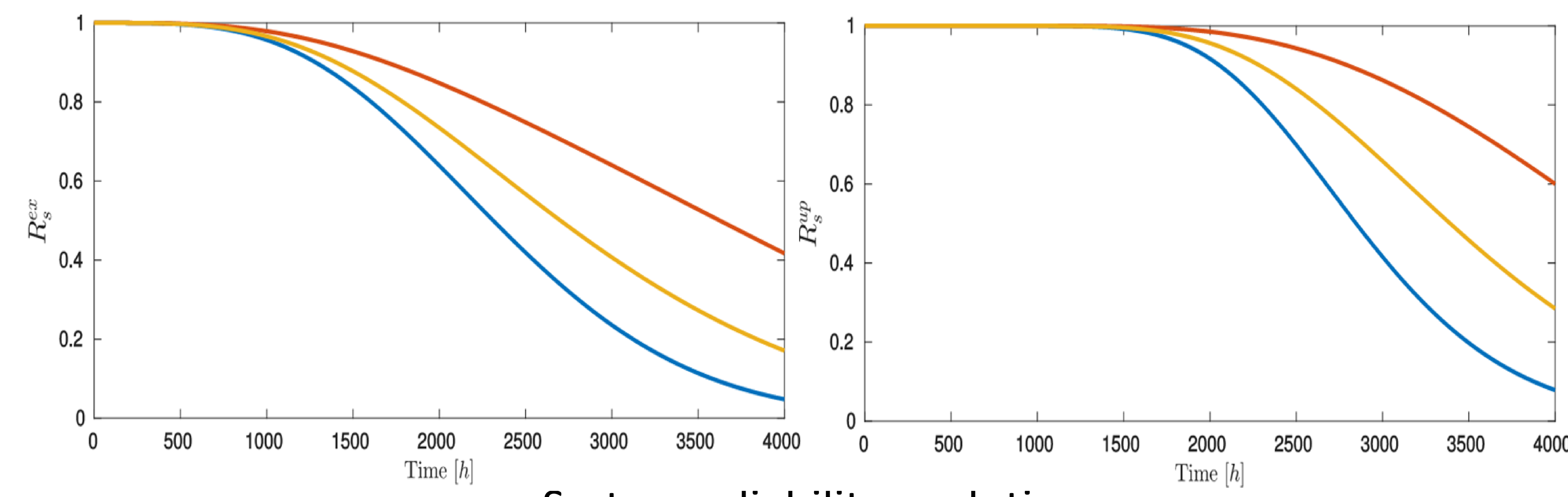
$$I_{B,i}^{up} = \frac{\partial R_s^{up}}{\partial R_i} \qquad \rho(k) = \hat{\boldsymbol{I}}_{\boldsymbol{B}}^{up}(k)$$



Control scheme

State of Research

Even with the approximate approach, better system reliability results than in the nominal case are obtained.



System reliability evolutions

Procedure	Exact [s]	Upper bound [s]
System reliability	0.0981	0.0608
Birnbaum's measure	0.5060	0.2329
TOTAL	0.6041	0.2937

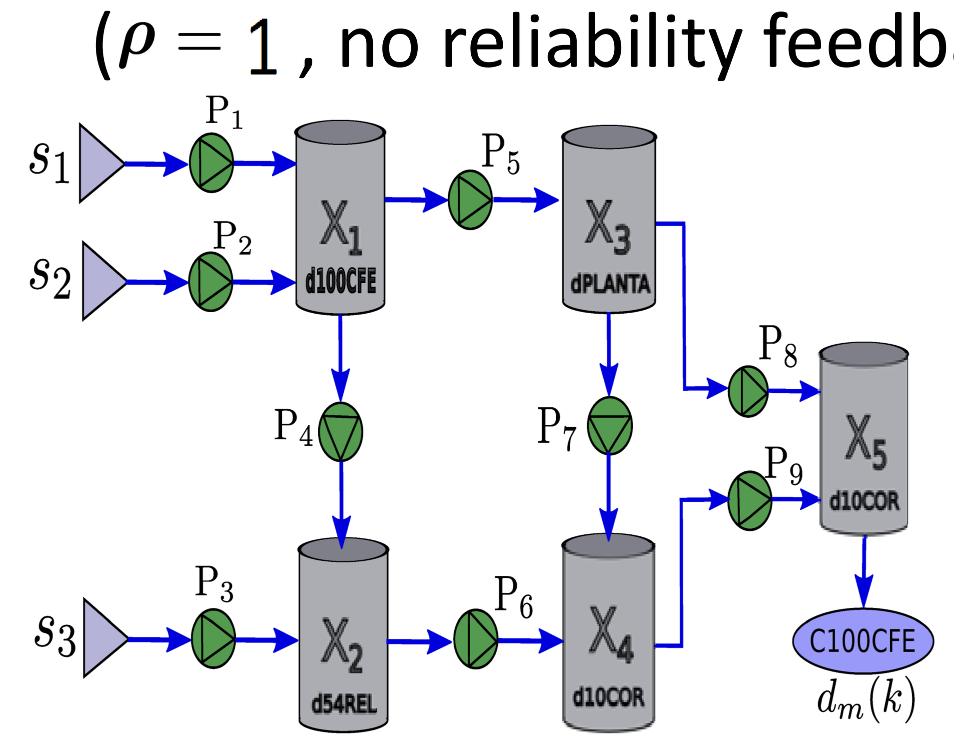
Computation times

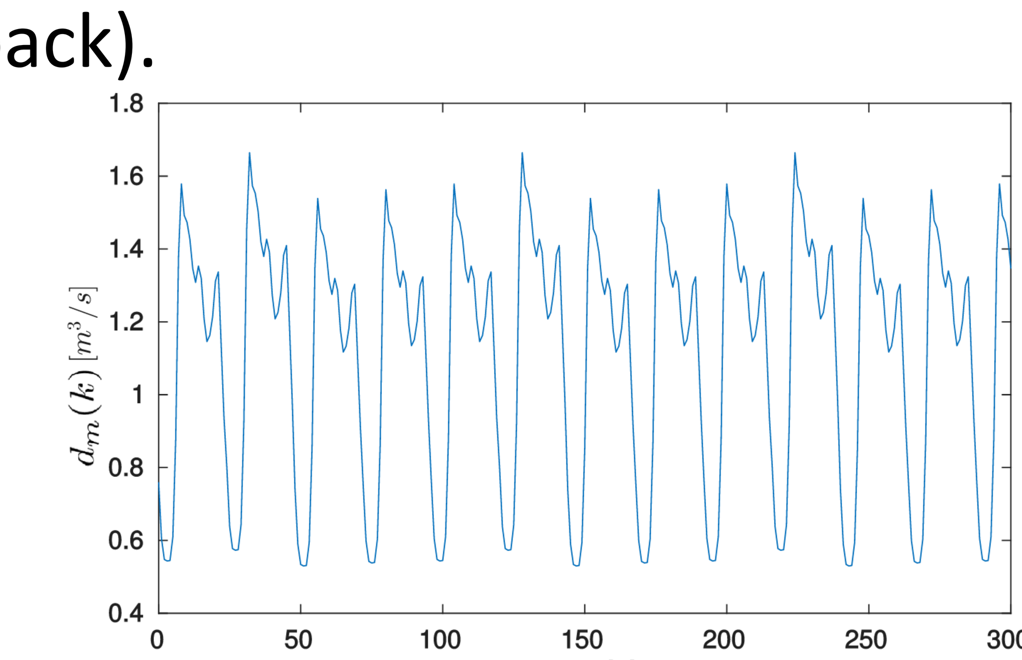
Next Steps

- These results encourage us to do further research in the domain of HAC for complex systems.
- Investigate the use of a system reliability lower bound approximation to implement the HAC methodology.

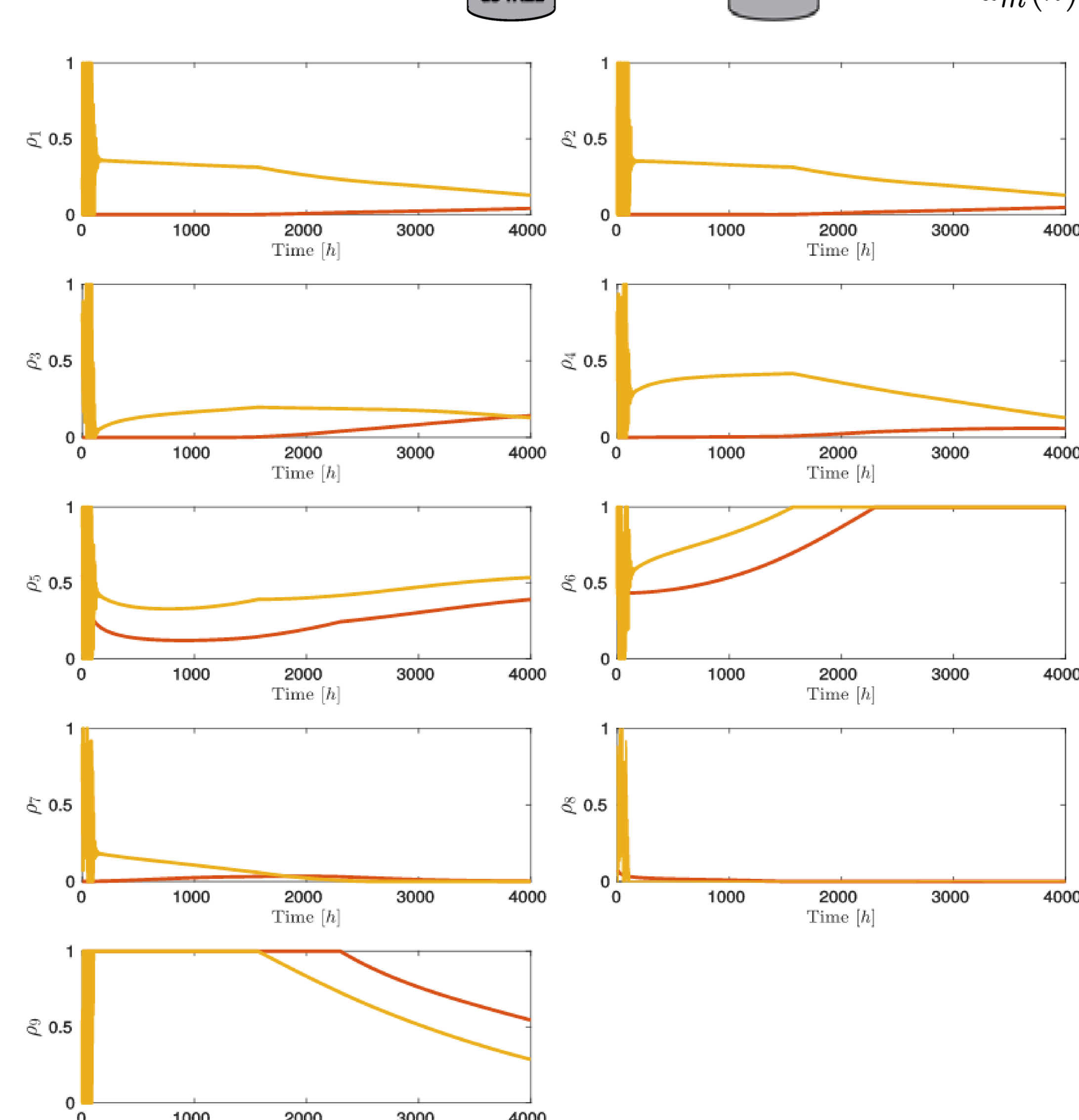
Comparative study

Three case studies: exact approach ($\rho(k) = \hat{\boldsymbol{I}}_{\boldsymbol{B}}^{ex}(k)$), approximate approach ($\rho(k) = \hat{\boldsymbol{I}}_{\boldsymbol{B}}^{up}(k)$), nominal approach ($\rho = 1$, no reliability feedback).

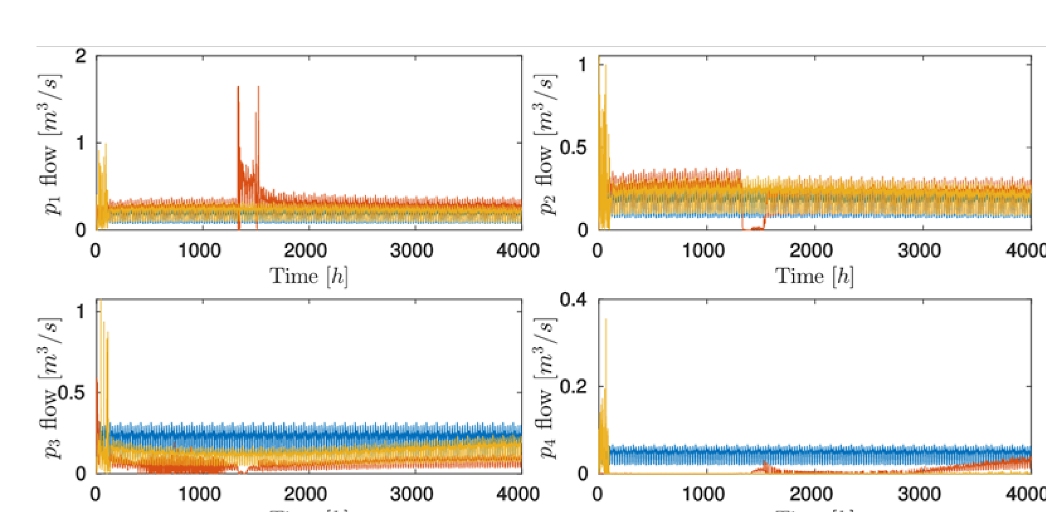




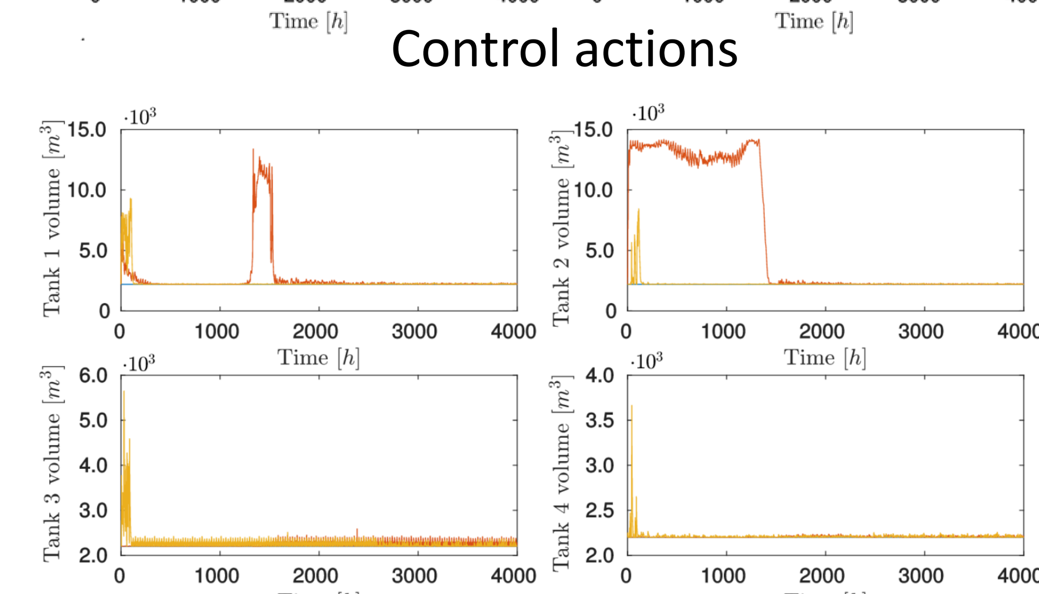
DWN and water demand



MPC weight evolutions



Control actions



Tank volumes

Acknowledgments and References

This work has been funded by the Spanish Ministry of Science and Technology through the projects CICYT HARCRICS (ref. DPI2014-58104-R), CICYT SCAV (ref. DPI2017-88403-R), and by the DGR of Generalitat de Catalunya (SAC group Ref. 2017/SGR/482).

[1] Salazar, J. C., Weber, P., Nejjari, F., Sarrate, R., & Theilliol, D. (2017). System reliability aware model predictive control framework. Reliability Engineering & System Safety, 167 , 663 - 672.