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

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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
   \[ P_j \]
2. Compute the structure function
   \[ \Phi_j(X) = 1 - \prod_{i=1}^{s} \left( 1 - \prod_{j \in P_i} X_j \right) \]
3. Compute the system reliability upper bound
   \[ R_{upper} = 1 - \prod_{j=1}^{s} \left( 1 - \prod_{i \in P_j} R_i \right) \]
4. Compute the components reliability
   \[ R_i(t) = e^{-\int_0^t \lambda_i(v) dv} \cdot \lambda_i(t) = \lambda_i^0 \left( 1 + \beta_i \int_0^t |u_i(v)| dv \right) \]
5. Compute the MPC weights based on a normalized component Birnbaum's measure
   \[ \rho_{upper,i} = \frac{\partial R_{upper}}{\partial R_i} \cdot \rho(k) = R_{upper}(k) \]

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

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 (\( \rho(k) = \hat{I}_{upper}(k) \)), approximate approach (\( \rho(k) = \hat{I}_B(k) \)), nominal approach (\( \rho = 1 \), no reliability feedback).

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