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Towards online adaptation of digital twins

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1 Background

Digital twins, a core component of cyber-physical systems, have gained a lot of attention recently. However, in the utilization of the technology on industrial applications, practical challenges arise from the continuous and real-time data integration. These challenges appear especially in the simulation and optimization and their integration with the continuous flow of data from the physical system.

The physics-based simulators tend to be computationally burdensome and not necessarily optimized for fast iterative computations. In addition, the current adaptation methods have great challenges to meet the real-time requirements in the applications, where the significant phenomena occur at rates from hertz to several kilohertz. Therefore, the research on real-time data integration is urgently needed to enable the development of practical digital twin applications.

This study focuses on the real-time adaptation of digital twins based on a mechanism guided by evolutionary optimization. The adaptation is required since the physical object is exposed to external impulses unknown to the presumed system state in the digital twin. The digital twin requires timely adjustment in order to adapt to the unpredictable changes observed in the state of the physical object.

2 Materials and methods

The proposed adaptation mechanism evaluates the deviation between the measured state of the real system and the estimated state provided by the model under adaptation. The deviation is minimized by adapting the model input based on an optimization algorithm. Differential evolution was selected as the optimization algorithm due to its impressive properties for multi-parameter global optimization.

The mechanism was tested by applying it on data generated via simulations. A physics-based model compiled in Simulink® environment was transformed into a lighter modeling approach, namely a surrogate model, to speed-up the iterative computations. This simplified model of the physical system was then used to test the adaptation mechanism.

The case study presents a digital twin application for a marine thruster. This novel product digital twin is developed to support the maintenance and lifecycle management of the physical products. The physical models in the digital twin enable torque estimation in the driveline also in the positions where the in situ measurement is not practical.

The adaptation mechanism was used to estimate constant values that represented the values of a model input variable in short time windows. The torque at the propeller was selected as the adapted input variable in the case study.

3 Findings and conclusions

The results reveal that low errors were achieved in the surrogate model output and in the estimated input variable. However, the real-time requirement was not achieved with the applied settings. Therefore, additional research should be done to reduce the computational time. Possible solutions include parallel processing, hardware-based speed improvements, algorithm optimization and the use of more efficient programming techniques. The application of the proposed mechanism on more complex problems and other practical digital twin applications is encouraged.