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DATA-DRIVEN REDUCED-ORDER MODELING TO SUPPORT ONLINE DECISION-MAKING FOR A SELF-AWARE AIRCRAFT

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We propose a data-driven reduced-order modeling strategy to assist online rapid decision-making for a self-aware unmanned aerial vehicle (UAV) that uses sensed structural data to estimate its structural state, uses this estimate to update its corresponding flight capabilities, and then dynamically re-plans its mission accordingly. This talk focuses specifically on structural assessment at the wing panel level. The approach is demonstrated for a test problem of a composite wing panel on a UAV that undergoes degradation in structural properties. Our strategy is to conduct finite element analyses over a range of damage scenarios in an offline phase and build a surrogate model that maps sensed quantities (strain) to structural capabilities (failure indices). In this way, we avoid conducting an expensive inference problem in the online phase, although we capture its essence through the offline construction of the surrogate models. Figure 1 summarizes the offline and online steps of the overall approach.

In the offline phase we build proper orthogonal decomposition (POD) [3, 5, 6] representations of the *measured quantities of interest*—quantities that are measured during flight using onboard sensors—and the *capability quantities of interest*—quantities employed in the decision process that give information about vehicle capability and performance constraints. For our panel demonstration problem, the measured quantities of interest are the normal and shear components of strain over the panel. The capability quantity of interest is the failure index, *FI*, which is an indicator of the structural condition that is translated into a scaling factor for maneuver parameters. *FI* is defined as the ratio between the experienced stress and the maximum allowable stress (typically the compression/tension/shear strength that characterizes the material properties) for each element in the finite element mesh. For each ply, five failure modes and related maximum allowable stresses are considered. We then use a self-organizing map (SOM) [4] to build a surrogate model that maps from the POD coefficients of the strain field representations to the POD

coefficients of the *FI* representation. In the online phase, gappy POD [1, 2] is used to estimate the POD coefficients of the strain field from sensor data.

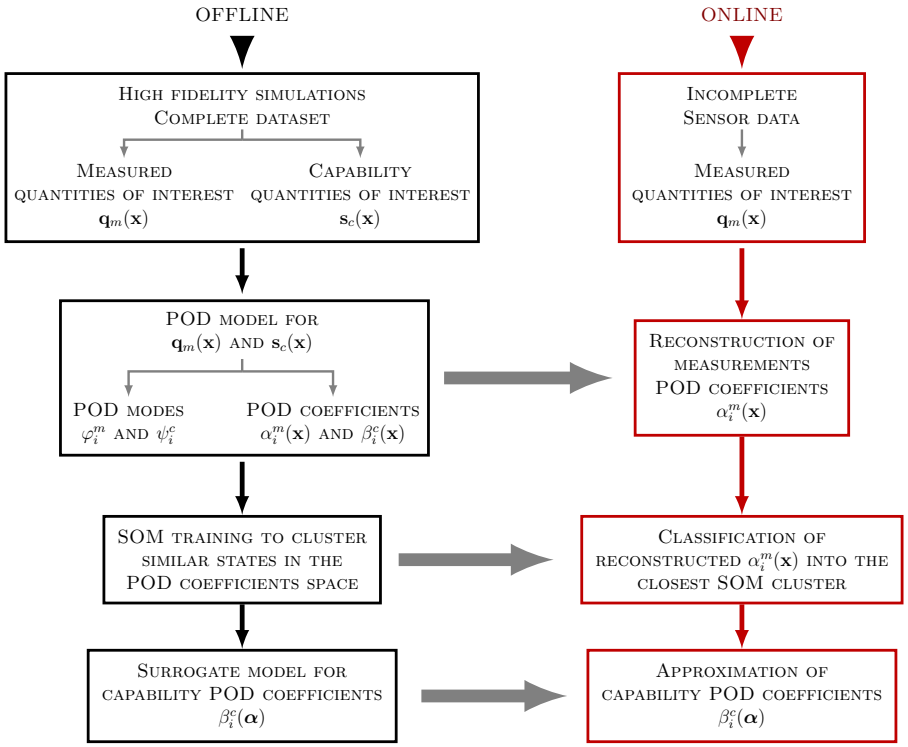

Figure 1: Diagram of the offline (black boxes) and online (red boxes) steps of our approach: POD models and SOM clusters are obtained offline and employed online as indicated by the gray arrows.

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