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Learning through action in mechanical systems via free energy minimization

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Active inference (AIF) is a neuroscience-inspired Bayesian framework for decision-making that unifies perception, action, and learning. It relies on a generative model interacting with a partially observable dynamical environment to minimize expected free energy [1]. We employ AIF agents to enable adaptive interaction with mechanical systems beyond passive data assimilation and conventional learning schemes. Within a physics-enhanced machine learning perspective, physical principles inform the structure of the generative model. Sensor data are embedded through reservoir computing [2], yielding a data-driven nonlinear state-space representation that captures the underlying system dynamics. Information gain about hidden states and model parameters drives active sensing and progressive refinement of the generative model through controlled interaction. Adaptation to unseen mechanical regimes is achieved via state expansion, allowing new scenarios to be incorporated without interfering with prior knowledge. Online learning is complemented by offline Bayesian model reduction to optimize the trade-off between model complexity and accuracy.

REFERENCES

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