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Reduced order modeling of parametrized systems through variational autoencoders and system identification

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Highly accurate numerical simulations conventionally rely on numerical modeling techniques such as finite element (FE) method, which might be extremely expensive when dealing with complex models. In particular, computational costs might become prohibitive when these models need to be queried for multiple combinations of control parameters and initial conditions.
Therefore, constructing efficient reduced order models (ROMs) that enable fast and accurate predictions while maintaining the physical phenomenon's dynamical characteristics is crucial [1]. In particular, an explicit modeling of the dynamics of the ROM would allow to predict unobserved behaviors, like, e.g., regime transitions, variation in multiplicity and stability of solutions [2].

We present a data-driven framework that combines ROM construction with reduced dynamics identification. This approach leverages variational autoencoder neural networks and parametric sparse identification of nonlinear dynamics to create a low-dimensional dynamical model which can be employed to efficiently estimate solutions at new parameter instances as well as to detect the main dynamical features of the observed phenomenon. The framework combines the expressiveness of neural networks with physical knowledge of the phenomenon, allowing prior knowledge to guide the choice of candidate ROMs and ultimately unveil the normal forms of the dynamics of observed phenomena. The effectiveness of the method is applied on a set of structural and mechanical dynamical systems.

References

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[2] Conti, P., Gobat, G., Fresca, S., Manzoni, A. and Frangi, A., 2022. Reduced order modeling of parametrized systems through autoencoders and SINDy approach: continuation of periodic solutions. In: *arXiv preprint,* arXiv:2211.06786.

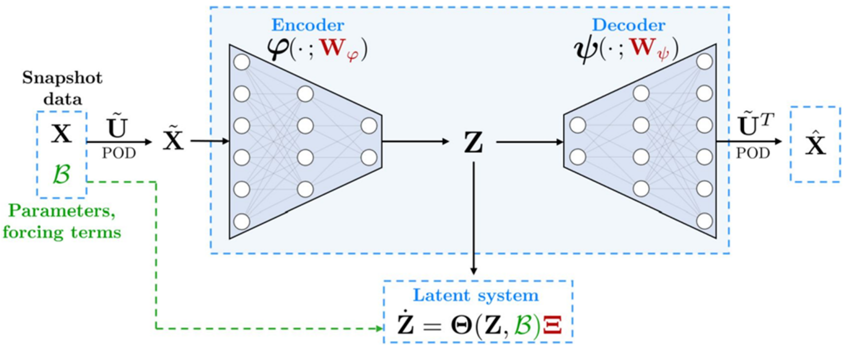

Figure 1: Schematic representation of the method which couples variational autoencoders with latent system identification.