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# Ship Motion Digital Twinning via Dynamic Mode Decomposition Approaches

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## ABSTRACT

Digital twins are widely considered enablers of groundbreaking changes in the development, operation, and maintenance of novel generations of products. They are meant to provide reliable and timely predictions to inform decisions throughout the product life cycle. One of their most interesting applications in the naval field is the digital twinning of ship performances in waves, a crucial aspect in design and operation safety.

This study focuses on i) ship motions nowcasting and ii) system identification for vessels operating in irregular waves. The two subjects are addressed using the dynamic mode decomposition (DMD). The short-term forecasting is tackled using Hankel-DMD [1]. The Hankel-DMD considers free-evolving dynamics and is suitable for accurately predicting ship motions up to five wave encounter periods from the knowledge of the immediate past, Fig. 2. The system identification task is approached using the Hankel-DMD with control [2] (Hankel-DMDc), an extension of the DMD that considers forced dynamical systems. Using the wave elevation and the rudder angle as forcing input, the method builds a ROM of the system characterized by remarkable accuracy, that can be used as a surrogate of the high-fidelity model it has been trained with, Fig. 1. Novel Bayesian extensions of the two methodologies including uncertainty quantification in the analyses are introduced and compared with the respective deterministic counterparts. The approaches result in data-driven, fast, accurate, and data-lean methods, particularly suitable for digital twinning, able to adapt in real-time the identified model with the data incoming from the physical system.

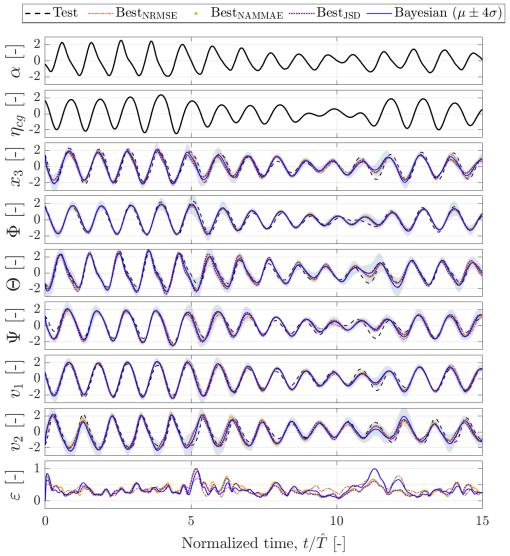


Figure 1: Hankel-DMDc system identification.

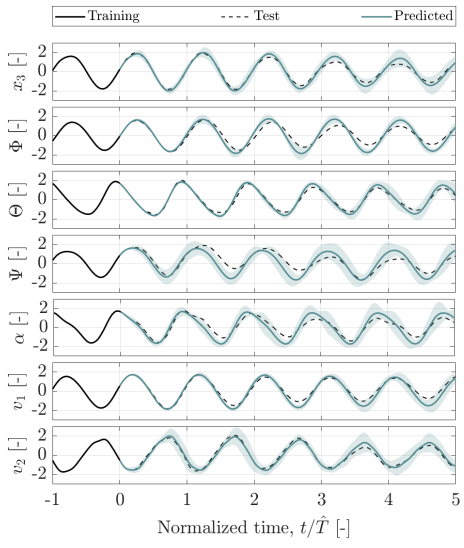


Figure 2: Hankel-DMD nowcasting.

## REFERENCES

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[2] J. L. Proctor, S. L. Brunton, and J. N. Kutz, "Dynamic mode decomposition with control," *SIAM Journal on Applied Dynamical Systems*, pp. 142–161, Vol. 15, No. 1, 2016.