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REDUCED ORDER MODELLING FOR DIGITAL TWIN

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An increasing number of disruptive innovations with high economic and social impact are characterizing the digitalization processes occurring in the last years. Despite the benefits of these developments, their speed and extent are limited by the available simulation technologies to handle complex models. The key idea of Digital Twin (DT) lies exactly in the creation of a digital counterpart of the physical asset able to replicate its behaviour. The necessity of a continuous and fast interaction between the physical and digital environments through background simulations has led to the introduction of Reduced Order Modeling (ROM) as crucial technology to simplify this simulation phase. ROM can indeed increase the speed of model execution while maintaining good level of accuracy and reducing the system degrees of freedom. In this way, DT can be applied to new complex fields, providing also more accurate information on the real counterpart thanks to the presence of ROM techniques.

Keywords: *model order reduction, digital twin, fluid dynamics*

1. Introduction

Digital twin (DT) [1, 2, 3] is one of the emerging technologies of Industry 4.0, aiming at the creation of smart products, processes, factories, and facilities. The primary concept behind Digital Twin involves developing a collection of interconnected models that can replicate the behavior of a physical asset. These models aim at offering dependable and swift estimations of all the relevant variables throughout the asset's entire operational lifespan, and make them accessible to users through a suitable interface [4]. The possibility of integrating a real asset with a virtual one leads thus to the creation of a Digital Twin able to interact with its physical counterpart by only receiving data from it or by a bidirectional exchange of data. The application of DT to some problems related to structural mechanics and fluid dynamics proposes new challenges. The request of accurate predictions of physical phenomena is essential for DT to get consistent results. However, these results can be obtained through high computational and time expensive simulations, leading to the infeasibility of simulating complex phenomena in real-time. A methodology to overcome this difficulty is represented by Reduced Order Modelling (ROM), which trades speed with a modest loss of accuracy [5]. The main benefit of ROMs comes from the presence of the offline-online paradigm. Firstly, in the offline phase the high fidelity simulations are performed for some given combinations of input parameters and the dominant dynamics are extracted to create the ROM. Based on the model constructed, in the online phase the evaluation of the magnitudes of interest simplifies in a linear superimposition of the modes multiplied by proper weights.

The benefits of the integration of ROMs and Digital Twin is thus twofold. On one side, ROMs enable to obtain more accurate information about the real counterpart, requiring low computational resources and real time simulations. On the other hand, ROMs can help in improving the quality of the products during the development phase by performing processes which are based on multi-query, e.g. optimization, uncertainty quantification, and controls. In this way, the coupling of DT with ROMs leads to a methodology deployable in many engineering contexts for several applications. Figures 1 and 1 provide some useful example of test cases. Figure 1 represents an example of a model used for a process of structural optimization, while in Fig. 2 the corresponding displacement field for a given loading condition is described.

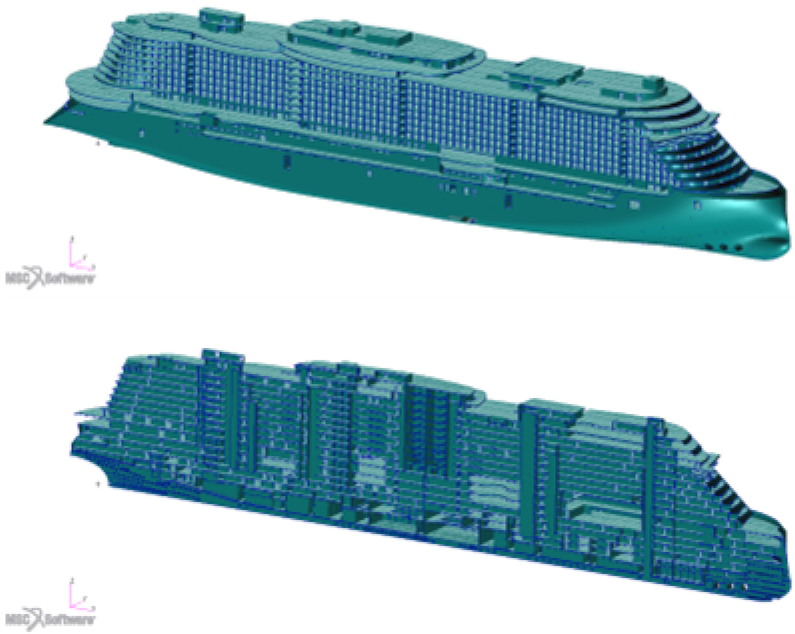

Figure 1: Example of a structural model in the naval engineering field. On the top the entire hull, while on the bottom a sectional view.

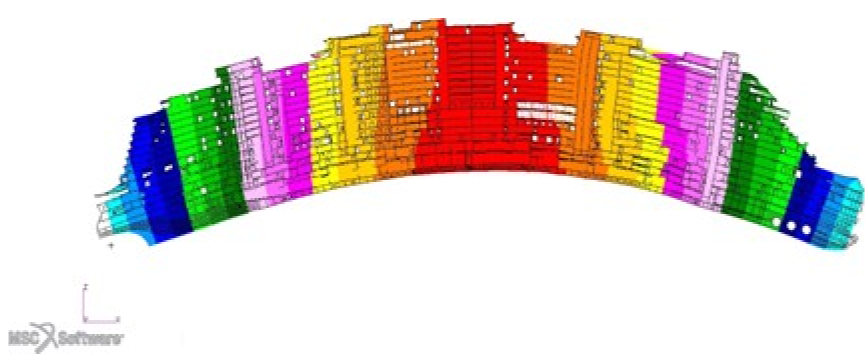

Figure 2: A modern cruise ship example of displacement field for the hogging loading condition.

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