DIGITAL TWINS EMPOWERED BY THERMODYNAMICS-INFORMED NEURAL NETWORKS

Alicia Tierz[1], Icíar Alfaro[1], David González[1], Francisco Chinesta[2,3], Elías Cuerto[1]

[1]ESI Group-UZ Chair of the National Strategy on Artificial Intelligence. Aragon Institute of Engineering Research. Universidad de Zaragoza. Zaragoza, Spain
[2] ESI Group chair. PIMM Lab. ENSAM Institute of Technology. Paris, France
[3]CNRS@CREATE LTD. Singapore.

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ABSTRACT

Digital Twins have become a transformative technology in the realm of engineering and industrial applications, enabling real-time monitoring, optimization, and predictive maintenance of complex systems. The accurate simulation of physical behaviors in Digital Twins is essential for ensuring their reliability and robustness, particularly in scenarios involving complex materials. Traditional computational methods, while accurate, often entail significant processing times due to the high dimensionality and non-linearity of such systems. In this work, we present an approach leveraging Thermodynamics Informed Graph Neural Networks (TIGNNs) [1] in a local form [2] to build highly efficient and accurate digital twins of hyperelastic solids. Our method integrates the GENERIC (General Equation for Non-Equilibrium Reversible Irreversible Coupling) [3] framework, a thermodynamics-based formalism, to ensure the consistency of the learned models. By incorporating thermodynamic principles directly into the network's architecture, we significantly enhance the physical plausibility and stability of the simulations.

The proposed TIGNN model is trained using a combination of geometric and thermodynamic biases, which not only reduces computational costs but also decreases the amount of synthetic data required. This approach results in a digital twin that accurately captures the response of viscous-hyperelastic structures under varying loading conditions, making it an invaluable tool for real-time simulation and predictive analysis.

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