Hybrid Neural Operator Framework for Long-Horizon Sloshing Prediction in Liquid Filling Processes

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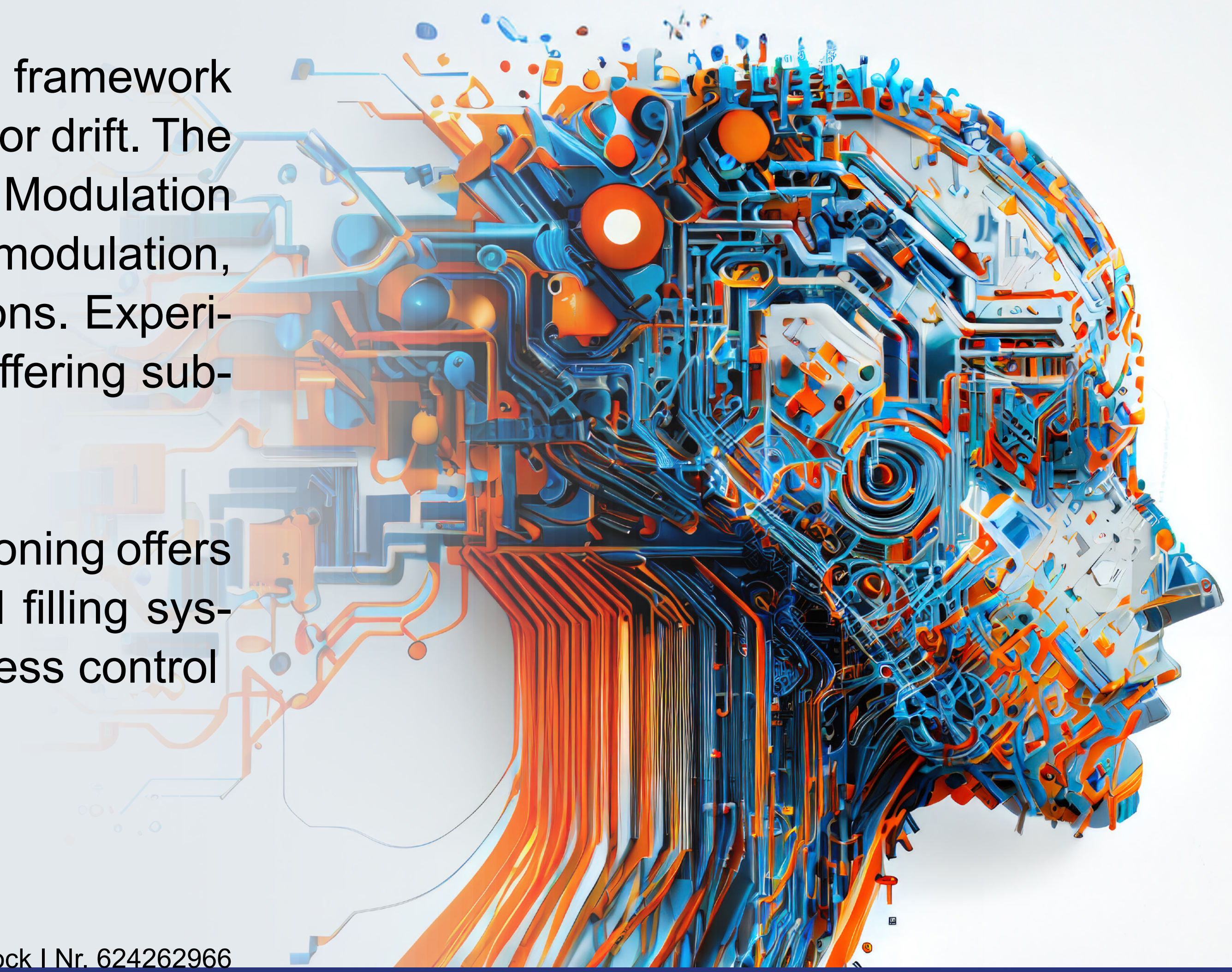
Accurate long-horizon prediction of fluid dynamics remains a central challenge in modeling sloshing behavior during industrial liquid filling processes. Traditional numerical simulation techniques, although highly accurate, are computationally demanding and therefore unsuitable for real-time or closed-loop industrial applications.

To overcome these limitations, this work introduces a hybrid machine learning framework that predicts extended fluid behavior sequences while mitigating cumulative error drift. The approach combines Neural Operator architectures with a Feature-wise Linear Modulation (FiLM) conditioning layer, inspired by recent developments in adaptive feature modulation, to enforce physical consistency and stabilize predictions over long time horizons. Experimental results demonstrate that this hybrid model preserves accuracy while offering substantial computational savings compared to traditional numerical solvers.

The findings suggest that integrating Neural Operators with FiLM-based conditioning offers a promising direction for efficient and reliable sloshing prediction in industrial filling systems, supporting future advances in real-time optimization and intelligent process control



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