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Physics-Informed Neural Networks for Parameterized Deformation of Ship Hulls with constant Hydrostatic Properties

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ABSTRACT

The present contribution describes an application of Physics-Informed Neural Networks (PINNs) to shape parameterization problems in ship hull design. More specifically, an ANN is employed to model the deformation law that acts o the given initial shape in order to produce a set of new geometries satisfying the user-defined physical constraints (e.g. length of the final object, surface smoothness). Thus, the developed network is trained by minimizing the penalization functions corresponding to the imposed constraints, such that it learns the desired deformation by solving an optimization problem. A similar application of ANN is presented in [1] so as to obtain the internal nodal displacements of a computational grid once the motion of the boundary nodes in specified. The present application is instead designed to deform a hull shape imposing a set of morphing parameters. In the marine engineering context, it enables the possibility to approximate the morphing law to apply to a given hull in order to obtain deformations that slightly differ from the original one on the geometric side while keeping some hydrostatic properties fixed. The computational pipeline developed is initially fed with an original hull shape specified in STL file format. A set of input parameters such as desired hull length, breadth, aspect ratio are then selected, as well as the specific hydrostatic properties (such as for instance immersed volume, longitudinal or vertical center of gravity) that must be preserved upon shape modification. One of the main goals of the investigation is that of establishing a relationship between the amount of input parameters considered, and the number of hull hydrostatic properties that can be retained so as to obtain a
well posed problem.

The main advantage of the shape parameterization methodology proposed, is that it results in hull modifications which do not alter the hydrostatic properties of the original hull. For such reason, it could be conveniently employed in computational fluid dynamic simulation campaigns carried out in late hull design stages, when no shape modifications affecting the ship equilibrium position and stability are desired.

REFERENCES

[1] Aygun, Atakan & Maulik, Romit & Karakus, Ali. (2023). Physics-Informed Neural Networks for Mesh Deformation with Exact Boundary Enforcement. 10.48550/arXiv.2301.05926.