A machine-learning-based zonal approach for turbulence modeling

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Turbulence models for the Reynolds-averaged Navier–Stokes equations (RANS) based on the eddy viscosity concept still are the most popular approach for Computational Fluid Dynamics (CFD) simulations. Nevertheless, universal models with good predictive capabilities remain a challenge.

In this work, machine learning is used to enhance the ability of existing turbulence models to provide acceptable results. The approach leverages a neural network to segment and identify different zones in the flow, and locally adapts the modeling of turbulence to the physical nature of each zone, via a proper combination of existing models that have been preliminarily tuned to work well in a small set of elementary structural flow zones. In this way the old-school zonal approach [1] becomes automatic. The basic idea is sketched in Figure 1.

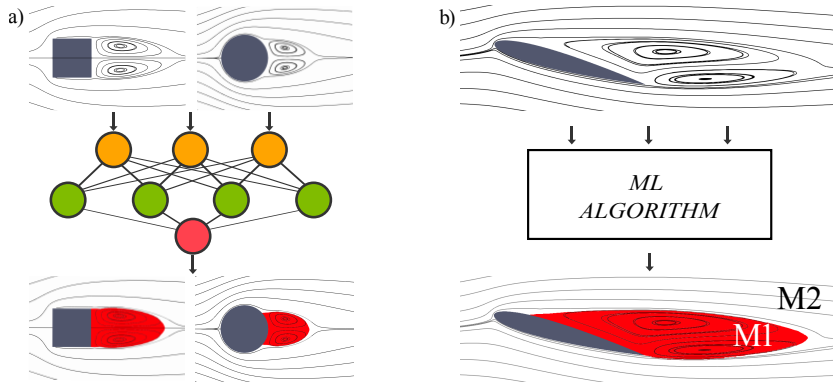

Figure 1: Schematic of the automatic zonal turbulence model: a) NN for semantic segmentation; b) On-the-fly zonal modeling, where a different model (M1 or M2) is applied to each automatically determined zone.

The idea is presented together with a preliminary implementation, in which only two flow zones are identified, and only two standard turbulence models are used. A test case (the flow over a wall mounted hump) unrelated to the training set demonstrates that, already in this oversimplified form, predictive capabilities are improved in comparison to the gold-standard $k-\omega$ SST (Figure 2).

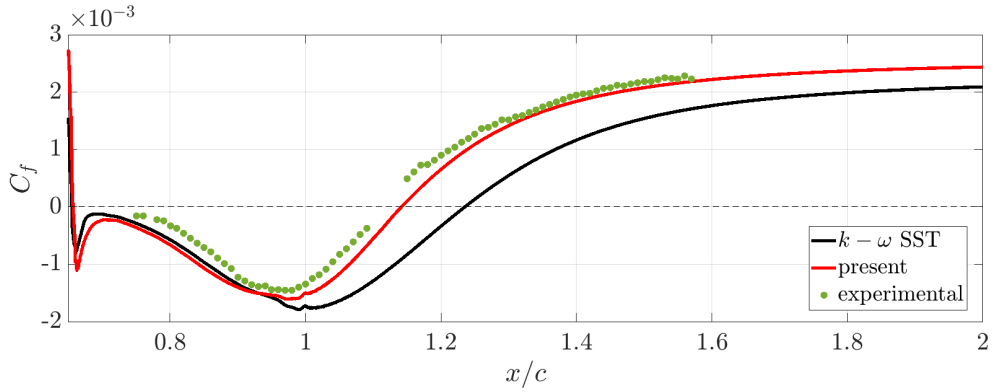

Figure 2: Skin friction coefficient evolution along a wall mounted hump for different turbulence models.

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[1] Avva et al., *AIAA 26th Aerospace Sciences Meeting* **15** (1988).