Proceedings of the 1st international Symposium on AI and Fluid Mechanics
Abstract No S5 A4

Automatic turbulence modelling

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

In this work we introduce a modern extension of the old-school zonal modelling concept [1], where machine learning, instead of being used to create better RANS models, is used to automatically enhance the ability of existing turbulence models to provide good results. With zonal modelling, one had to know the solution in advance, to separate the flow field into zones with distinct physical structures, such that each zone can be assigned a specific turbulence model tailored to the zone itself. Our automatic turbulence model (ATM) crucially dispenses with the need of knowing *a priori* the flow zones, and identifies them at run-time via an U-net neural network. The concept is sketched in Figure 1.

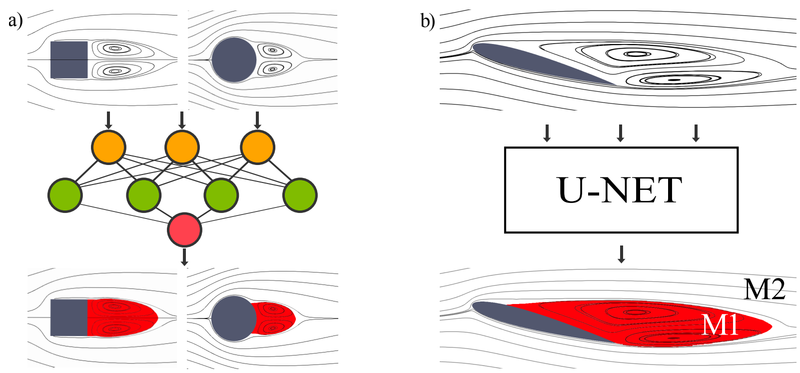

Figure 1: Schematic of ATM modelling: a) offline training of the neural network for semantic segmentation to classify regions of the flow field according to a dictionary of zones; b) On-the-fly zonal modeling, where a different model (M1 or M2) is assigned run-time to each zone, automatically identified by the U-net.

We will present the idea alongside with a preliminary implementation of ATM, in which only three flow zones are identified, and only two standard turbulence models are used. Test cases demonstrate that, already in this oversimplified form, ATM performs better than the gold-standard $k-\omega$ SST model (Figure 2).

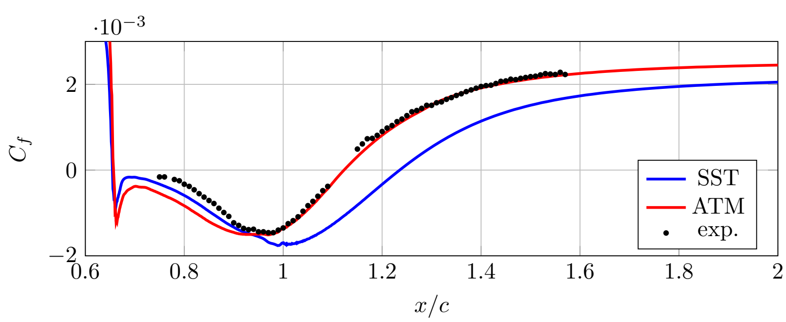

Figure 2: Skin-friction coefficient evolution along a wall mounted hump, Comparison between SST and ATM.

Keywords: turbulence modelling, machine learning, neural networks, turbulent flows

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