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Sweep events characterization through CNN

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Sweep events in a fully turbulent channel flow were characterized through a Convolutional Neural Network (CNN) applied to data from direct numerical simulations at $Re_\tau = 365$ using a Fourier-Chebyshev spectral code [1]. A sweep event was identified as a connected region, with a volume exceeding 30^3 wall units, in which the instantaneous pointwise tangential Reynolds stress $\tau(x,y,z) = -u(x,y,z)v(x,y,z)$ satisfies $|\tau(x,y,z)| > Hu'(y)v'(y)$, where H is the hyperbolic hole size set to 1.75, and u' and v' are the RMS of the streamwise (u) and wall-normal (v) velocity fluctuations [2]. After tracking the characteristic parameters of the sweep event over time, a CNN was employed to construct a latent space for clustering the different trajectories. Moreover, a first attempt to predict τ_{avg}, which is the volumetric average of τ over the sweep volume, has been carried out. For this purpose, a Long Short Term Memory (LSTM) model composed of one layer with 32 hidden units was applied, followed by a three-layer feed-forward neural network with ReLU activation function and layer sizes of 32, 16, and 1. The model is trained with a database of 1024 identified independent sweep events, using the time history of u in two points, $\boldsymbol{x_1}^+ = [x_c^+, 10, z_c^+]$ and $\boldsymbol{x_2}^+ = [x_c^+, 30, z_c^+]$ at the same streamwise (x_c^+) and spanwise (z_c^+) position of the centroid of the event, as indicated in figure 1(a). The length of the time history corresponds to 7.5 viscous time units, discretized with a time step of $\Delta t^+ = 0.5$. We found a good agreement between the predicted τ^*_{avg} and the true value τ_{avg}, obtained from the validation dataset, as shown in figure 1(b). Using this model, we were also able to characterize other volume-averaged properties of these events. Future analyses will further investigate the potential of the LSTM network to predict the temporal evolution of these same quantities.

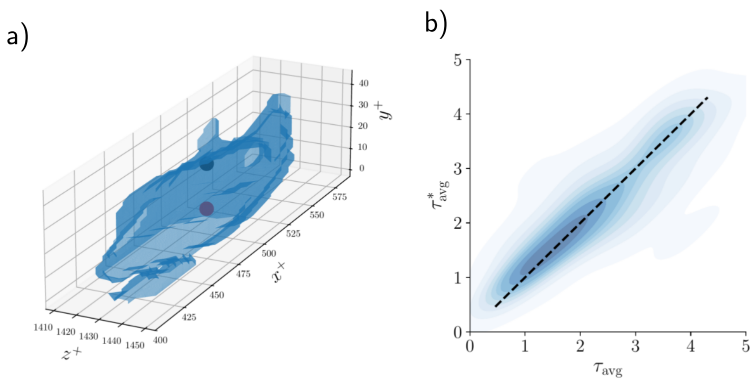

Figure 1: a) Visualization of a detected sweep event. The dots represent points $\boldsymbol{x_1}$ (red) and $\boldsymbol{x_2}$ (black). b) Joint PDF of τ_{avg} (true value) and τ^*_{avg} (predicted value).

References

[1] D. Zaza and M. Iovieno. On the preferential concentration of particles in turbulent channel flow: The effect of the added-mass factor. *Energies*, 17(4), 2024.

[2] A. Lozano-Durán, O. Flores, and J. Jiménez. The three-dimensional structure of momentum transfer in turbulent channels. *J. Fluid Mech.*, 694:100–130, 2012.