JHTDB SAMPLE TURBULENCE ASSIGNMENT

Prepared by Dr. Jin Lee and Prof. Tamer Zaki for use during the 2015 Turbulence Summer School (Univ. Maryland)

Using the JHU public turbulence database to explore basic aspects of turbulence:

1. Go to http://turbulence.pha.jhu.edu and familiarize yourself with the database.

2. Download the folder with the Matlab scripts.
   Request a token by emailing: turbulence@pha.jhu.edu
   This exercise will use the channel flow database, which can be specified in the Matlab script using:
   dataset = 'channel'

3. Visualization: (Do not use spatial or temporal interpolation)
   a. Write a Matlab script to read a sub-area of the x-z plane
      $17 < x < 21$
      $y = -0.985$
      $1 < z < 2$
      at time t=0 and plot contours of u, v and w(x,z).
   b. Repeat the same task for a sub-area of the x-y plane
      $17 < x < 21$
      $-1 < y < 0$
      $z = 0$
      and plot contours of u, v, and w(x,y).
   c. Extract a *sub-sampled* volume of data using successive queries of x-z planes
      $0 < x < 6$ (96 points)
      $-1 < y < 0$ (16 points)
      $0 < z < 2$ (48 points)
      and plot a 3D isosurface of u(x,y,z).

4. Averages
   Extract a *sub-sampled* volume of data using successive queries of x-z planes
   $0 < x < 8\pi$ (64 points)
   $-1 < y < 0$ (48 points)
   $0 < z < 3\pi$ (32 points)
   Perform streamwise and spanwise averaging of the velocity.
   a. Plot U(y) in linear and semilog scales.
   b. Improve the estimate of U(y) by querying a second snapshot.
   c. Perform the same tasks to compute and plot the Reynolds stresses R_{ij} versus y.

5. Two-point correlations using Fourier transform:
   Request a *sub-sampled* plane of the data:
   $0 < x < 8\pi$ (256 points)
   $y = -0.8$
   $0 < z < 3\pi$ (128 points)
   Evaluate the u-perturbation velocity by subtracting the local x-z average.
   Compute the two-point correlation in the x-z plane and plot $R_{uu}(\Delta x, \Delta z)$ contours.
   Extract the streamwise profile at $\Delta z=0$;
   Also extract the spanwise profile at $\Delta x=0$.

SAMPLE TURBULENCE ASSIGNMENT

Using the JHU public turbulence database to explore basic aspects of turbulence:

1. Spectral analysis

   Request a *sub-sampled* plane of the *channel* flow data:

   $0 < x < 8\pi$ (256 points)

   $y = -0.8$

   $0 < z < 3\pi$ (128 points)

   Evaluate the u-perturbation velocity by subtracting the local x-z average.

   a. Perform Fourier transform in the streamwise direction and low-pass filter the data with a cutoff equal to $2\pi/\delta$. Now perform a second Fourier transform in the spanwise direction and low-pass filter with cutoff equal to $2\pi/\delta$. Visualize the original and the filtered fields.
   b. Evaluate and visualize the energy spectra in the streamwise wavenumber averaged over all spanwise locations.
   c. Evaluate and visualize the energy spectra in the spanwise wavenumber averaged over all streamwise locations.

2. Conditional averages

   Extract a *sub-sampled* volume of data using successive queries of x-z planes

   $0 < x < 8\pi$ (40 points)

   $-1 < y < -0.8$ (20 points)

   $0 < z < 1$ (50 points)

   Perform streamwise and spanwise averaging of the velocity.

   a. Evaluate the perturbation velocities and perform quadrant analysis of the Reynolds shear stress. Improve the accuracy of the analysis by querying a second snapshot.
   b. Compute the conditionally averaged perturbation velocity vector in the y-z plane. The condition for averaging is an ejection event ($u' < 0$ and $v' > 0$) at the reference wall-normal position $y_{ref}=-0.95$. The spanwise size of the conditional averaging window should be 0.2 (thus the reference position is within the interval $0.2 < z < 0.8$). Visualize contours of $\langle u'|Q2\rangle$ and vectors of $(\langle v'|Q2\rangle, \langle w'|Q2\rangle)$ in the y-z plane.
      Improve the accuracy of the analysis by querying a second snapshot.

3. Structure identification

   Extract a *sub-sampled* volume of data using successive queries of x-z planes at t=12

   $0 < x < 5$ (64 points)

   $-1 < y < 0$ (48 points)

   $0.8 < z < 1.8$ (48 points)

   Perform streamwise and spanwise averaging of the velocity, and evaluate the u' perturbation field.

   a. Visualize isosurfaces of the original u-perturbations at the threshold $u_{th}=-0.1$.
   b. Perform a Gaussian filter in the cross-flow plane with $\sigma = 0.1\delta$ and subsequently a low-pass filter in the streamwise direction with cutoff $2\pi/\delta$. Evaluate the x-z average $\langle u'_{filter}\, u'\rangle / \langle u'u'\rangle$. Visualize isosurfaces of the filtered u-perturbations at $u'_{filter} = u_{th} (\langle u'_{filter}\, u'\rangle / \langle u'u'\rangle)$.
   c. Perform streak detection by identifying local extrema in the z-y plane within the isosurface from step (b). Plot the cores of the identified structures in three-dimensional space.