# QSQH Prediction Model User Manual

This is the user manual which instructs the users of the QSQH prediction model from the preparation of datasets to the computation of the output. The stream-wise and span-wise directions are represented by $(x, z)$ respectively, and their corresponding velocity components are assigned with $(u, w)$.

1. The QSQH prediction model requires the input of the large-scale filtered wall friction of an objective velocity field, and produces the statistical predictions of this objective field.

2. The work package of the QSQH prediction model consists of the code and the universal velocity field respectively which are in the format readable on MATLAB. The QSQH prediction model is currently available on MATLAB only.

3. The large-scale filter is currently limited to wavelength cut-offs of $\lambda_x^+ = 2000\pi$ and $\lambda_z^+ = 250\pi$ by which the universal velocity field is generated. More options of the large-scale filter will be made available in the future.

4. The users should prepare the snapshots of the wall friction of the objective velocity field. It is also feasible if the probability density function of the wall friction is available that a set of data points of the wall friction should be generated by the users in advance.

   The model requires the input of the dataset of $u_{\tau_L,i}(x,z)$ and $\theta_i(x,z)$ which are defined as:

$$u_{\tau_L,i}(x,z) = \sqrt{\frac{\tau_{L,i}(x,z)}{\rho}} \tag{1}$$

$$\theta_i(x,z) = -\tan^{-1}\frac{\tau_{L_z,i}(x,z)}{\tau_{L_x,i}(x,z)} \tag{2}$$

   where the subscript $i$ is the index of the snapshots and $L$ stands for "large-scale filtered"; $\tau$ is the wall shear stress and its subscripts $x, z$ stand for the wall friction in stream-wise and span-wise directions respectively; $\rho$ is the flow density; the resultant large-scale filtered wall friction is calculated as: $\tau_L = \sqrt{\tau_{L_x}^2 + \tau_{L_z}^2}$.

5. If the wall friction is not directly available, an alternative approach is to estimate the wall friction by the wall shear stress as such:

$$\tau_{L_x,i}(x,z) = \left.\frac{\partial u_{L_i}(x,z)}{\partial y}\right|_{\text{wall}}, \; \tau_{L_z,i}(x,z) = \left.\frac{\partial w_{L,i}(x,z)}{\partial y}\right|_{\text{wall}} \tag{3}$$

6. The dataset of $u_{\tau_L}$ and $\theta$ should be arranged into two-dimensional matrices of $u_{\tau_L,i}(x,z)$ and $\theta_i(x,z)$ , and stored as "u_tauL_index.mat" where the "index" refers to the index of the snapshots from which the input dataset is generated. The mean values $\langle u_{\tau_L,i}(x,z)\rangle$ and $\langle \theta_i(x,z)\rangle$ should be calculated and stored. Note that the angular bracket is the operator of averaging on $i$, $x$ and $z$.

7. The user interface of the model is named as "*interface.m*" which allows users to specify their input data. The universal velocity field "*vel_tilde.mat*" and the uniform reference wall-normal grid "*y.mat*" need to be downloaded to a local directory which needs to be specified by the users in the input section of the interface. The directory of the storage of $u_{\tau_L}$ and $\theta$ also needs to be specified. Note that the users need to input the size of each $u_{\tau_L,i}$ and $\theta_i$, and the indices of the files storing them. What's more, an output directory is required to store the computation results.

8. The output of the model contains following elements:

   - Local velocity profiles of stream-wise and span-wise velocity component: $u_j(y)$ and $w_j(y)$ (1-D array);
   - One-point statistics of the predicted velocity field: $U(y)$, $\langle u'^2\rangle(y)$, $\langle w'^2\rangle(y)$;
   - Wall-normal grid: $y$;
   - Number of $NaN$ value ignored by the operation of averaging.

   Note that since the local $y$ profile differs from data point to data point, there are few data points in the wall-normal direction towards the outermost $y$ grid point in some velocity profiles have no value because linear interpolation is implemented in the model and few query points locate outside the local $y$ profile. Please read the reference papers for the thorough explanation on the variation of local $y$ profiles. The author found that the number of $NaN$ value is insignificant comparing with the total number of data points, hence they should have negligible impact on the calculation of one-point statistics.

9. There is no limit in units for the users preparing the user-defined input data, the output velocity field will be the same in units as the input data.