User manual: QSQH synthetic model

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1 Introduction

1.1 Purpose

QSQH synthetic model is a synthetic turbulence model, generating wall-bounded turbulent velocity field This user manual provides instructions on how to use the software of this model. The stream-wise, wall-normal and span-wise directions are represented by (x, y, z) respectively.

1.2 System Requirements

- Environment: MATLAB 2023b or later
- RAM: 16 GB or more
- Disk Space: 25GB or more

1.3 Installation

Download the QSQH synthetic model, and the dataset for testing, from Google drive. Extract the files from the downloaded rar file to a folder on user's own device.

The main body of QSQH synthetic model consists of the following files:

- `Interface.m`
- `Data_converter.m`
- `QSQH_model_1D.m`
- `QSQH_model_3D.m`

- `y_ref.m`

- `progressbar.m`

Note that "`progressbar.m`" is an additional function downloaded from MATLAB FileExchange.

Other folders contain the test dataset of the input friction field and universal velocity field, as well as the reference output which is for the user to validate their test output, meaning the statistics of the output generated by the user should coincide with the statistics of the reference output.

2 Getting Started

2.1 Launching the code

To launch the model, launch MATLAB on user's own device first. Open the "`Interface.m`" file in MATLAB to see the user interface of the model. Make sure the current folder in the MATLAB is the folder where the downloaded files are extracted.

2.2 Input parameters

The user is required to input some parameters at the interface.

1. The size of the input friction field. The values of L_x^+ and L_z^+ are already prescribed that $L_x^+ = 8000\pi$ and $L_z^+ = 3000\pi$ for the test input friction field.

2. Choose the dimension of the output velocity field to be 1D or 3D.

3. Choose the maximum spatial ranges in x and z direction in wall unit, where $x^+_{\text{max}} \in \{0, 204\}$ and $z^+_{\text{max}} \in \{0, 120\}$. For the test, these values should be set to $x^+_{\text{max}} = 0$ and $z^+_{\text{max}} = 0$ for the 1D case, or $x^+_{\text{max}} = 204$ and $z^+_{\text{max}} = 120$ for the 3D case.

4. Also choose the outermost wall-normal position y^+_{max} and the position nearest to the wall y^+_{min}, where $y^+ \in \{0, 100\}$. For the test, $y^+_{\text{max}} = 50$ and $y^+_{\text{min}} = 0$ for the 1D case, or $y^+_{\text{max}} = 10$ and $y^+_{\text{min}} = 0$ for the 3D case.

5. Confirm whether this run is a test. Choose the logical value of true for the test.

6. Choose the starting loop. Choose the value of 1 for the test.

7. The rest of the required parameters are the directories of the dataset which will participate in the computation of the model. They are already prescribed at the interface, and should remain unchanged for the test, unless the file separator is different for the operation system of the user's device.

2.3 Progress of the work

The model is now ready to be run from the interface, by clicking the "Run" button. The progress bar will appear to give the information of the progress in percentage and the time left for completing one loop. A message will be displayed at the command window to inform that the computation of a loop is finished. Thereby, the user can monitor the progress of the work of the model.

Essentially, larger number of the loop means that more instances of the output velocity field are generated, thereby more statistically representative the output is. The progress will automatically terminate when all the points of the input friction field are used in the computation. For the test, the user can stop or pause the progress at loop = 8 for the 1D output, and loop = 5 for the 3D output.

2.4 Output of the model and test

The output of the 1D QSQH synthetic model will be the instances of the synthetic velocity profiles in the wall-normal direction, where the outermost position $y^+_{\max} = 50$ as defined in Section 2.2. The output matrix files are of the size: $N_t \times N_\tau \times N_y = 1 \times 65536 \times 54$, where N_t is the number of snapshots of the input wall friction ($N_t = 1$ for the test input), and N_τ is the number of points from which the wall friction is sampled, therefore, $N_t \times N_\tau$ yields the number of instances generated by the model. Note that N_y is the grid points of the synthetic velocity profiles in wall-normal direction.

The output of the 3D QSQH synthetic model will be the instances of the synthetic velocity field of a uniform grid of the size: $x^+_{\max} \times z^+_{\max} \times y^+_{\max} = 204 \times 120 \times 9.7$, with $\Delta x^+ = 12$ and $\Delta z^+ = 6$. The output matrix files are of the size: $N_t \times N_\tau \times N_x \times N_z \times N_y = 1 \times 1024 \times 18 \times 21 \times 19$, where $N_x \times N_z \times N_y$ are the grid points of the synthetic velocity field in x, z and y directions.

Now open the "`Stats_calculator.m`" file in MATLAB. Without any changes to the input parameters, run the file and it will calculate the mean velocity profile $U^+(y^+)$ and stream-wise velocity variance $\langle u'^2 \rangle^+(y^+)$ of the 1D output, and the two-point correlation coefficients of the stream-wise velocity in wall-parallel directions $R_{u'}(\Delta x^+)$ and $R_{u'}(\Delta z^+)$ of the 3D output.

These statistics will also be plotted with the statistics of the reference output. If the statistics of the user generated output coincide with the reference output, this confirms that the user has installed and run the model correctly.

2.5 Preparing your own input data

The above procedures and dataset are for the user to test the model. There are larger universal velocity field database available:

- Download the 1D universal velocity field from Google drive.
- Download the 3D universal velocity field from Google drive.

The user may wish to proceed to prepare their own input friction field, and use the proper universal velocity field database to generate the synthetic velocity field. The user should prepare the data of wall shear stresses in x and z directions, as different snapshots in the form of MATLAB matrix files of the size of $N_x^* \times N_z^*$, where N_x^* and N_z^* are the number of grid points in stream-wise and span-wise directions of the wall friction field. The matrix files should be named as: "`tau_xxxxx.mat`" where "`xxxxx`" stands for the time or the indices of the snapshots. Note that the input data should be prepared in wall units. Once the input data is prepared, and the universal velocity field database is downloaded, the user can open the interface again, and change the input parameters accordingly as described in Section 2.2, then run the model to generate the synthetic velocity field.