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 with the Statistics and Machine Learning Toolbox and the requires Curve Fitting Toolbox installed.
- RAM: 16 GB or more
- Disk Space: 25GB or more

1.3 Installation

Download the "`QSQH_tool.rar`" from Github, and the "`test_dataset.rar`" from Google drive. Extract the files and folders in these two rar files to the same folder. This folder is referred to as the folder of the QSQH tool in the following content.

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

- `QSQH_model_1D.m`
- `QSQH_model_3D.m`

- `InputParameters_1D.m`
- `InputParameters_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.

Now you have completed the installation, and need to test it.

2 Test of the installation

1. Launch MATLAB. Open the files "`QSQH_model_1D.m`" and "`QSQH_model_3D.m`" in MATLAB. Make sure the current folder in the MATLAB is the folder where the downloaded files are extracted.
2. Press the Run button in MATLAB to run "`QSQH_model_1D.m`" and "`QSQH_model_3D.m`" respectively, and wait until the end of the calculation. On an average laptop it should take about 2 minutes for "`QSQH_model_1D.m`", and 15 minutes for "`QSQH_model_3D.m`".
3. Open Stats_calculator.m and press Run.
4. You will see a plot of the mean velocity and the root mean square of the fluctuation velocity obtained by the calculation together with the reference data, and a plot of two point correlations with the reference data, too. If they coincide, the installation was successful.

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3 Getting Started

3.1 Prepare your own input data

The dataset used in Section 2 are for only the test the installation. The user needs to prepare their own input data to generate the synthetic velocity field. The input data must be the friction field which is obtained from the wall shear stresses of a user-decided turbulent velocity field that is statistically homogeneous in x and z directions. The user needs to obtain the wall shear stresses $\tau_x^+(x^+, z^+)$ and $\tau_z^+(x^+, z^+)$ in wall units, from the temporal snapshots that have huge time interval from each other, for example, approximately one flow-through time.

The snapshots of $\tau_x^+(x^+, z^+)$ and $\tau_z^+(x^+, z^+)$ must be stored 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. Note that $N_x \times N_z$ must be the same as the grid points of the velocity field from which the friction field is obtained. The user needs to take a note of the size of the stream-wise and span-wise domain in wall unit, L_x^+ and L_z^+ for later use. The matrix files should be named as: “`tau_xxxxx.mat`” where “`xxxxx`” stands for the time step or the index of the snapshot. The snapshots should be sufficient so that the friction field is statistically representative. The number of snapshots denoted N.

Create a new subfolder in the folder of the QSQH tool. Store the files of the snapshots of the friction field in this subfolder. The input data is ready for use.

3.2 Databases of the universal velocity field

Download the universal velocity field database:

- 1D universal velocity field.
- 3D universal velocity field.

Create two new subfolders in the folder of the QSQH tool. Extract the files in “`Universal_velocity_fi` and “`Universal_velocity_field_3D.rar`” to these two subfolder respectively.

3.3 Input parameters

Apart from the input data of the friction field, the input parameters of the tool must be changed accordingly to the input data and the universal velocity field used. The input parameters of the tool are stored in “`InputParameters_1D.txt`” and “`InputParameters_3D.txt`” for the 1D and 3D model respectively. Open these two `txt` files in MATLAB. On the left of the comma, there are the names of the input parameters, and on the right of the comma, they are the values of these input parameters. These values are set for the test when you first open the `txt` files.

`InputParameters_1D.txt`:

- `Lx` stands for the size of the stream-wise domain L_x^+ of the input friction field in wall unit.

- `Lz` stands for the size of the span-wise domain L_z^+ of the input friction field in wall unit.
- `xmax` stands for the user-defined size of the stream-wise domain x_{max}^+ of the output synthetic velocity field in wall unit. Set $x_{\mathrm{max}}^+ = 0$ for 1D model.
- `zmax` stands for the user-defined size of the span-wise domain z_{max}^+ of the output synthetic velocity field in wall unit. Set $z_{\mathrm{max}}^+ = 0$ for 1D model.
- `ymin` stands for the user-defined closest wall-normal position to the wall y_{min}^+ of the output synthetic velocity field in wall unit. You are free to choose in the wall-normal range of $y^+ \in \{0, 100\}$.
- `ymax` stands for the user-defined outermost wall-normal position y_{max}^+ of the output synthetic velocity field in wall unit. You are free to choose in the wall-normal range of $y^+ \in \{0, 100\}$. Note that $y_{\mathrm{max}}^+ > y_{\mathrm{min}}^+$.
- `test` tells the model whether this upcoming run is for the test of the installation, the file names of the output for the test will be marked with the ending "`test`". Set it to true for the test, or false for proper run.
- `starting_loop` stands for the starting loop of the calculation, denoted b_{start}. Set $b_{\mathrm{start}} = 1$.
- `dir_input_folder` stands for the folder name of the input friction field. Change it to the name of the subfolder storing the user prepared input friction field, between the file separators "\". (Change the file separator if it's different in your system)
- `dir_vel_tilde_folder` stands for the folder name of the universal velocity field. Change it to the name of the subfolder storing the database of the 1D universal velocity field downloaded in Section 3.2.
- `dir_output_folder` stands for the folder name of the 1D output synthetic velocity field. Create a subfolder that will be storing the 1D output files in the folder of the QSQH tool, if you have not done so. Change the value of `dir_output_folder` to the name of the subfolder that will be storing the 1D output synthetic velocity field.

`InputParameters_3D.txt`:

- `Lx` stands for the size of the stream-wise domain L_x^+ of the input friction field in wall unit.
- `Lz` stands for the size of the span-wise domain L_z^+ of the input friction field in wall unit.

- xmax stands for the user-defined size of the stream-wise domain x^+_{max} of the output synthetic velocity field in wall unit. You are free to choose in the range of $x^+_{\text{max}} = 0, 204$ for 3D model.

- zmax stands for the user-defined size of the span-wise domain z^+_{max} of the output synthetic velocity field in wall unit. You are free to choose in the range of $z^+_{\text{max}} = 0, 120$ for 3D model.

- ymin stands for the user-defined closest wall-normal position to the wall y^+_{min} of the output synthetic velocity field in wall unit. You are free to choose in the wall-normal range of $y^+ \in \{0, 100\}$.

- ymax stands for the user-defined outermost wall-normal position y^+_{max} of the output synthetic velocity field in wall unit. You are free to choose in the wall-normal range of $y^+ \in \{0, 100\}$. Note that $y^+_{\text{max}} > y^+_{\text{min}}$.

- test tells the model whether this upcoming run is for the test of the installation, the file names of the output for the test will be marked with the ending "test". Set it to true for the test, or false for proper run.

- starting_loop stands for the starting loop of the calculation, denoted b_{start}. Set $b_{\text{start}} = 1$.

- dir_input_folder stands for the folder name of the input friction field. Change it to the name of the subfolder storing the user prepared input friction field, between the file separators "\". (Change the file separator if it's different in your system)

- dir_vel_tilde_folder stands for the folder name of the universal velocity field. Change it to the name of the subfolder storing the database of the 3D universal velocity field downloaded in Section 3.2.

- dir_output_folder stands for the folder name of the 3D output synthetic velocity field. Create a subfolder that will be storing the 3D output files in the folder of the QSQH tool, if you have not done so. Change the value of dir_output_folder to the name of the subfolder that will be storing the 3D output synthetic velocity field.

The model is now ready to be run for the user prepared input, by running "QSQH_model_1D.m" and "QSQH_model_3D.m".

3.4 Output of the model and test

The output files are in the form of "`.mat`" files. 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 is at $y^+_{\max}$ as defined in "`InputParameters_1D.txt`". The output matrix files are of the size: $N^* \times N^*_\tau \times N^*_y$, where N^*_t is the number of snapshots of the input friction field, and N^*_τ is the number of points sampled from each snapshot of the friction field, 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 which has the grid of the size: $x^+_{\max} \times z^+_{\max} \times y^+_{\max}$, with the grid spacing $\Delta x^+ = 12$ and $\Delta z^+ = 6$. The output matrix files are of the size: $N^* \times N^*_\tau \times N^*_x \times N^*_z \times N^*_y$, where $N^*_x \times N^*_z \times N^*_y$ are the grid points of the synthetic velocity field in x, z and y directions.