User Guide for CSC 1.0

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This document is intended as a quick-start guide for CSC 1.0. Access to MATLAB version 2015b or higher is required to use CSC 1.0.

Description

CSC 1.0 is a MATLAB Graphical User Interface (GUI) for computing coherent structure coloring (CSC) fields from 2D or 3D particle trajectory data. The algorithm computes the CSC corresponding to each particle in a time-series of particle position data.

Files

**README.pdf**: this file
CSC.p: main GUI file
CSCinput.m: editable MATLAB file containing the processing parameters
Example (folder): sample input data described below

Usage

Opening the GUI
Uncompress the software package **CSC1.0.zip** and assign the folder containing the files listed above as the Current Folder in MATLAB (e.g. browse from the toolbar at the top of the MATLAB Command Window). At the prompt in the Command Window, run the GUI by typing **CSC;** and pressing return. The GUI will appear:
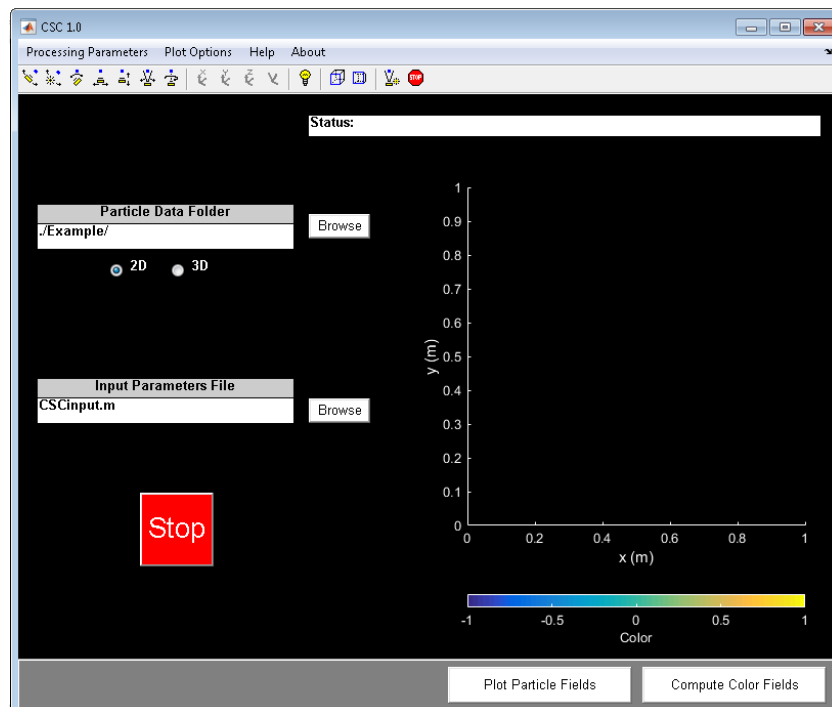
Particle Position Files
To run the GUI, the user must specify the location of the folder containing the particle trajectory data. Each particle position data file (e.g. one per time step) must contain the Particle ID (an integer that is unique among the particles) and the X, Y coordinate values for each particle in the field. This data should be formatted in adjacent delimited columns, e.g. for N particles in a 2D data set:

ID1, X1, Y1
ID2, X2, Y2
...
IDN, XN, YN

For 3D data, the Particle ID and X, Y, and Z coordinates should be included.
Each particle position file should contain an identical prefix string and a sequential numeric suffix, e.g. quadgyre_1.dat, quadgyre_2.dat, etc.

Note: Each particle position file must contain every particle ID, even if some particles are not present in a given particle position file (e.g. due to incomplete/partial trajectories). The position coordinates of missing particles should be identified as NaN for the X, Y, and Z (if applicable) coordinates.

Processing Parameters
The Processing Parameters file can be edited in two ways. The first method is by opening the file **CSCinput.m** in the MATLAB Text Editor, changing the relevant values, and saving the file. The second method is by selecting "Processing Parameters" from the menu at the top of the GUI window. Upon selecting the "Edit" option, the **CSCinput.m** file will automatically open in the MATLAB Text Editor, where changes to the relevant values can be made and saved. To ensure that you have properly saved the desired parameter values, select the "View" option, which will open a separate window displaying the current values of the Processing Parameters.

Plotting the Input Trajectory Data
To verify that your input particle trajectory data is properly formatted, press the "Plot Particle Fields" button. The particle fields will be plotted on the right-hand side of the GUI window, with the direction of particle motion indicated by an arrow after the first time step. The time delay between the display of successive particle fields is specified in the **CSCinput.m** file.

The particle fields can be zoomed, panned, rotated, etc. by selecting the corresponding icons on the toolbar at the top of the GUI window after the last particle field is displayed or if plotting is terminated early by pressing the "Stop" button.

Note: Remember to select the correct dimension for your data using the radio buttons on the left-hand side of the GUI window.

Computing and Exporting Coherent Structure Coloring Data
Once you have verified that the input particle trajectory data is properly formatted, press the "Compute Color Fields" button. The Status bar at the top right-hand side of the GUI window updates the progress of the calculation and provides alerts in the event of program errors. To terminate execution of the program at any time, press the "Stop" button.

The algorithm will first load each of the particle position data files. Depending on the current processing parameters in the **CSCinput.m** file, the computed CSC fields will be plotted and (optionally) saved. Be sure to select an **outroot** that is the distinct from the **inroot** so that the input files are not overwritten by the exported data.

The columns of data exported for 2D calculations are (units in parenthesis):
Particle ID, x (m), y (m), color (dimensionless)

The columns of data exported for 3D calculations are (units in parenthesis):
Particle ID, x (m), y (m), z (m), color (dimensionless)

Additional options such as the GUI color theme and axis label editing are available in the "Plot Options" menu.


Example

Steady Quadruple-Gyre Flow
The input trajectory data for 300 randomly distributed particles during 2000 time steps is contained in the **Example** folder (e.g. **quadgyre_1.dat**). The processing parameters in the **CSCinput.m** file for this example are as follows:

```
args = struct(...
    'datafolder'            , './Example/', ...
    'inroot'                , 'quadgyre_', ...
    'outroot'               , 'CSC_quadgyre', ...
    'first'                 , 1, ...
    'last'                  , 2000, ...
    'increment'             , 1, ...
    'numformat'             , '%d', ...
    'fileextension'         , '.dat', ...
    'separator'             , ',', ...
    'numheaderlines'        , 0, ...
    'lengthcalib_axis'      , 1, ...
    'numparticlefields'     , 1000, ...
    'export_first'          , 1, ...
    'export_last'           , 2000, ...
    'export_increment'      , 100, ...
    'xoutnodes'             , 64, ...
    'youtnodes'             , 64, ...
    'zoutnodes'             , 64, ...
    'plot_delay'            , 1, ...
    'export_data'           , 1, ...
    'export_format'         , 'ascii' ...
  );
```

Upon selecting the Particle Data folder and pressing the "Plot Particle Fields" button, the corresponding particle fields are plotted with a time delay of 1 second between each frame.

Upon pressing the "Compute Color Fields" button, the CSC field is computed, displayed, and saved as an ASCII text file.

Quadruple-Gyre Particle Field (top) and CSC Field (bottom)
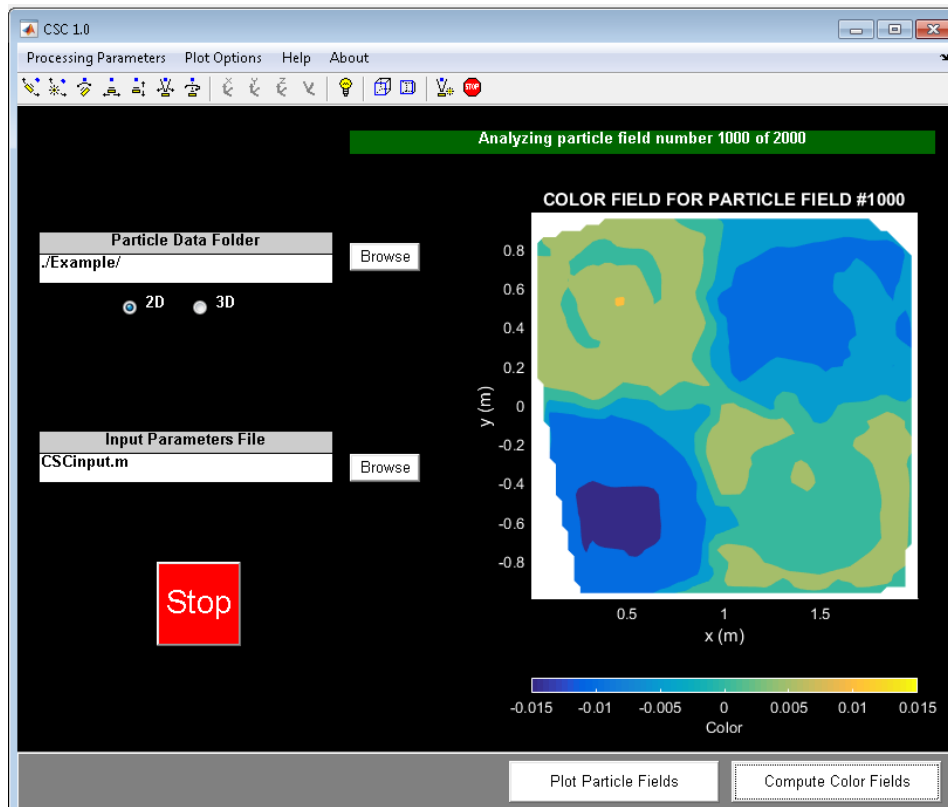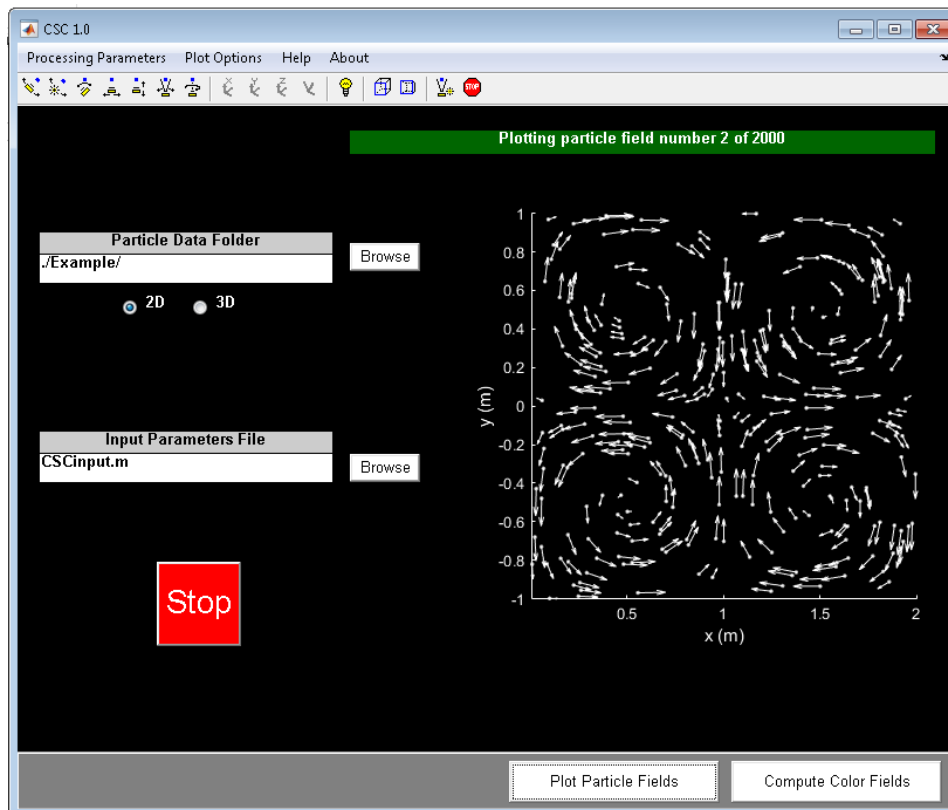
Run Time

As a point of reference for the run time of CSC 1.0, this section provides an evaluation of a flow with 500 to 20,000 particles tracked over 201 time steps. For each case, one CSC field was calculated at the final time step using data from all 201 time steps.

All runs were completed on a single core of a 3.5 GHz Intel Xenon processor with 32 GB of RAM. For this hardware configuration, the recommended maximum number of particles is 20,000 due to RAM constraints. This limit should be revised commensurate with the RAM capacity of your hardware.

In the table below, the total run time for each case is partitioned according to the time it takes to load the particle trajectory data; calculate the adjacency, degree, and graph Laplacian matrices; perform the eigendecomposition; plot the data (assuming no user-specified plot delay); and export the CSC vector and field data. All times are given in seconds.

Number of particles	Total time (sec)	Load data	Calculate matrices	Eigen-decomposition	Plot data	Export data
500	4.5	0.3	1.6	0.1	0.1	2.4
1,000	8.8	0.4	5.6	0.3	0.1	2.4
5,000	153.3	1.2	133.5	16.1	0.1	2.5
10,000	692.9	2.0	555.7	132.5	0.1	2.6
15,000	1685.1	3.1	1261.8	417.2	0.2	2.8
20,000	3178.7	4.0	2244.7	926.7	0.3	3.0