

Data assimilation toolbox for scalar conservation laws: Java implementation manual

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Abstract

This document describes the use of the tester developed for the article *On sequential data assimilation for scalar macroscopic traffic flow models*. The tester was designed as a toolbox for comparative assessment of performance of data assimilation methods for scalar conservation laws discretized using the Godunov numerical scheme. The filtering algorithms implemented are the extended Kalman filter (EKF) and the ensemble Kalman filter (EnKF). The flux functions implemented are the Greenshields flux, the Newell-Daganzo flux and the quadratic-linear flux. The tester, this manual and other resources are available for download at <http://traffic.berkeley.edu/downloads>.

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2 Publishing results using the software

If you publish results using the Java toolbox, please refer to the following article in your work:

S. BLANDIN, A. COUQUE, A. BAYEN AND D. WORK. On sequential data assimilation for scalar macroscopic traffic flow models. *Submitted to Physica D: Nonlinear Phenomena*, 2011.

The corresponding pdf is included in the zip file which you downloaded.

3 How to: launch the toolbox

This software requires a functional Java Virtual Machine (JVM). Most computers will have one by default. Otherwise, it can be downloaded from the following url : <http://www.java.com/en/download/manual.jsp?locale=en>.

To launch the tester, simply double-click on the .jar file. If this does not work, try right-clicking on the .jar file and selecting an option which might launch the tester (for example, on some Linux distributions, the default behavior is opening an archive manager). On UNIX systems, you may need to flag the .jar file as executable.

Please make sure to completely read this manual before launching the toolbox. The software includes a less detailed help as well.

4 How to: use the “data assimilation” toolbox

This section describes the function of each button of the interface, and details the sequence of actions required to start a test using the toolbox. Each of the following subsections refers to one of the thematic boxes depicted in figure 1.

4.1 Red block: model parameters

The left section of the interface allows the definition of the parameters of the flux function of the scalar conservation law. Using the tabs, you can choose the model the tester runs with: Greenshields flux function, Daganzo-Newell (DN), quadratic-linear (QL). In particular the number of parameters differ between the models.

- **Maximal density:** defines the maximum density, also called jam density.
- **Maximal flow:** defines the maximum value for the flux function, also called capacity.

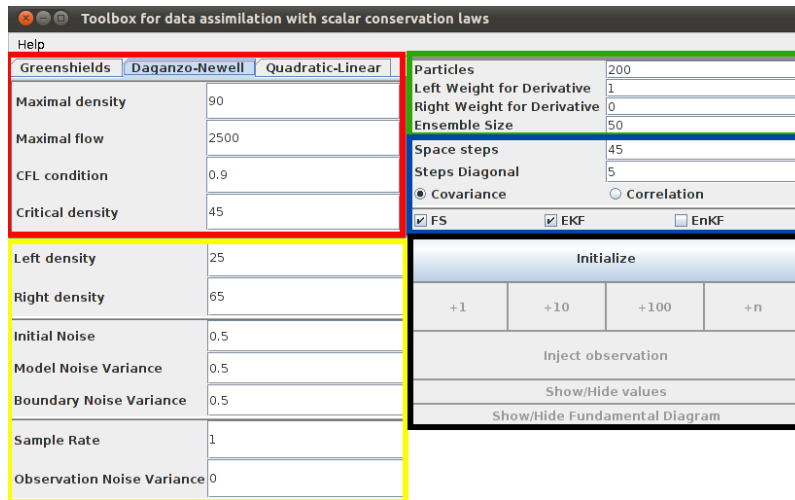


Figure 1: Thematic division of the toolbox interface.

- **CFL condition:** defines the value for the *Courant-Friedrich-Lewy* constant, which should be lower than 1 for stability of the Godunov scheme. In the current implementation, given the model and model parameters, this defines the value of the ratio $\frac{\Delta t}{\Delta x}$.
- **Critical density:** density value at which the flow is maximal (only available for the Daganzo-Newell flux function and the quadratic-linear flux function).

Note : Clicking the *Initialize* button and then the *Show/Hide Fundamental Diagram* button will show you the fundamental diagram corresponding to the parameters you defined.

4.2 Yellow block: problem data

- **Left density, Right density:** defines the left and right initial density values for the Riemann problem.
- **Initial noise:** defines the variance of the normal centered additive random variable associated with the initial condition.
- **Model noise variance:** defines the variance of the normal centered random variable added to the state at each iteration of the numerical scheme.
- **Boundary noise variance:** defines the variance of the normal centered random variable associated with the boundary conditions.
- **Sample rate:** ratio of space cells for which an observation is injected at the analysis step of the filter. A sample rate of 1 means that an observation is injected in each cell.
- **Observation noise variance:** defines the variance of the normal centered random variable added to the observations injected.

4.3 Green block : filter parameters

- **Particles:** defines the number of samples used in the Monte-Carlo forward simulation (FS).
- **Left/right weight for derivative:** weights used for linear convex combination of the left and right derivative at states for which the flux function is not differentiable. This is used by the extended Kalman filter (EKF) at stationary entropic shock waves. The sum of the two weights should be one.
- **Ensemble size:** the number of ensemble members in the ensemble Kalman filter (EnKF) algorithm

4.4 Blue block : simulation parameters

- **Space cells:** defines the number of space steps used in the Godunov scheme discretization.
- **Steps diagonal:** the diagonal of the covariance matrix of the state estimate is displayed only for time steps multiple of this quantity. Setting this parameter to 5 means that only one value every 5 time steps is stored.
- **Covariance/Correlation:** choice of covariance or correlation for display.
- **FS/EKF/EnKF:** algorithms which are ran, Forward simulation (FS), extended Kalman filter (EKF), ensemble Kalman filter (EnKF).

4.5 Black block : simulation commands

- **Initialize:** this button loads the parameters and initializes the algorithms. If you change the parameters later on, they will not be taken into account until you push the *Initialize* button again (please note that this will also restart the simulation). You are not be able to push any other button until you have initialized.
- **+1/+10/+100/+n:** these buttons allow you to propagate the current state forward in time for n time steps. Once the calculation for these steps is completed, intermediate results are displayed : the graph of the current state mean, the state error covariance matrix, and the evolution of the covariance diagonal for the different filters ran (for this latter figure the unit of the vertical axis is the number of time steps divided by the parameter “Steps Diagonal”).
- **Inject observation:** this button allows to inject an observation at the set sampling rate from the current state of the forward simulation and use it as an observation in the filters.
- **Show/Hide values:** this button displays additional windows with the numerical results corresponding to the graphics displayed.
- **Show/Hide fundamental diagram:** this button displays the fundamental diagram corresponding to the model and parameters chosen.

Note: below the commands a white console displays the status of the current calculations.

4.6 First use

All parameters have default values so you can run the simulation right away and visualize how the toolbox works.

If you specify new values of the parameters, once you are done, push *Initialize* to start the simulation. Then push one of the $\pm n$ buttons to calculate the next n steps. Results will be displayed at the end of the calculations.

If you want additional results or numerical results corresponding to the displayed graphics, push *Show/Hide values*.

After having propagated the state forward in time, you can push *Inject Observation*. The observation will be assimilated by the filter at the next time step, and displayed on a separate graphics.

An example of a run is displayed in figure 2.

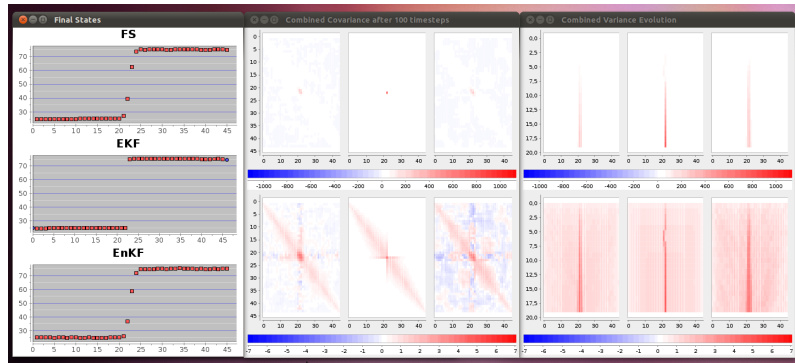


Figure 2: Example of results after a 100 steps simulation with default parameters

5 How to: use the “distribution of uncertainty” toolbox

The toolbox: “Distribution of uncertainty on true state”, allows one to represent the full distribution of uncertainty during the sequential data assimilation process.

The User Interface is very similar to the interface of the toolbox “Data assimilation for scalar conservation laws”. Here we describe specifically its additional fields and functionalities.

- **Sample size:** number of particles displayed at once.
- **Number of histograms:** the number of cells for which an histogram is displayed. The cells are the middle cells; e.g. with 60 cells, selecting 6 histograms yields the histograms for cells 27, 28, 29, 30, 31 and 32.
- **Histogram bars:** number of bars in the histogram.

- **New Sample:** displays another sample of particles. Its size is defined by the field “Sample size”.
- **Show/Hide Sample values:** displays the numerical values of the current sample.
- **Copy cell values:** copies to clipboard the value of the cell with index specified by the user in the pop-up window.