BarrierTool Manual

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In this brief manual the user is guided through the GUI of BarrierTool by means of an example. To launch the GUI, the user needs to go to the folder "Main" and type the command "null_geo" in the command prompt.

1 Detection Method

The first thing the user has to decide is whether he wants to detect Lagrangian or Eulerian barriers. One should select the former if he is interested in structures intrinsically tied to a specific finite time interval over which they exert their influence on nearby trajectories and the latter if he is particularly interested in the short-term limit of the former. In the following sections of this tutorial we present the Lagrangian case, as it is more general, and we demonstrate an example of the Eulerian limit at the section 6.

In the Lagrangian setting one can look for Closed Diffusion Barriers or Elliptic Lagrangian Coherent Structures. In principle, the distinction between the two lies on the different variational principles they should satisfy. These principles are described in detail in [1] and [2], both of which are included in the folder "doc". One should experiment with both options to extract larger structures.

Once the detection method is chosen, the user has to select the range and number of values for \mathcal{T}_0 or λ . In case of lagrangian coherent structures, one needs also to specify the time interval on which they want to detect structures. In the diffusive setting such a choice is extraneous since the underlying theory suggests that we use the time-averaged version of the Cauchy-Green strain tensor for our computations.

Another thing that is worth mentioning is the admissible range of values for \mathcal{T}_0 or λ . In every case that we tried the default range of these values produced barriers. However, this does not preclude the existence of flows where this range needs to be larger. This is why we suggest that the user experiment with this range.

2 Averaged Diffusive Cauchy-Green Tensor Field

The first step for the detection of barriers is the computation of the right Cauchy-Green strain tensor in case of lagrangian coherent structures or its time-averaged version in the diffusive setting. To this end, the GUI accepts as input a ".mat" file containg the velocity field. More specifically, this file must contain five variables, i.e., the variables "time", "vx", "vy", "xc" and "yc" corresponding to the time instances for which the velocity field is known, the x and y components of the velocity field and the x and y coordinates of the grid on which the velocity field is defined, respectively. In case of material diffusion barriers, the user needs to specify three additional variables, i.e., "D11", "D12" and "D22" corresponding to the components of the symmetric diffusive structure tensor. For the majority of diffusive cases this tensor can be set to identity. One may find an example of the acceptable file structure in the folder "data", namely, in the file "ocean_velocity_example_diffusive.mat".

To demostrate the use of GUI, we detected material diffusion barriers for the default set of \mathcal{T}_0 values using the file "ocean_velocity_example_diffusive.mat". Once we selected this file, we used the values shown in Figure 1 for the computation of the time-averaged Cauchy-Green strain tensor.

Detection	Method	Closed Diffusion Barriers
		Integration Options
👻 Lagrangian Darriers	Eulerian Barriers	Interpolation in the Physical Space
Closed Diffusion Barriers		Step Size: 0.01
- <i>τ</i>		Number of Cores Used: 11
Lower 70 value:	0.5	
Upper 70 value:	2	Compute Closed Diffusion Barriers
Number of \mathcal{T}_0 values:	20	
C Elliptic Lagrangian C	oherent Structures	Plots and Output
Time Interval:	30	Compute Outermost Closed Diffusion Barriers and Plot
Lower λ value:	0.8	Compute outcomest crossed principal parties and not
Upper λ value:	1.2	
Number of λ values:	20	Advection of Closed Diffusion Barriers
		Load Velocity Field
Averaged Diffusive Cau	chv-Green Tensor Fie	Id Minimum x: -12
		Maximum x: 29
ocean_velocity_exa	mple_diffusive.mat	Minimum y: -45
Minimum	x: -4	Maximum y: -19
Maximum	x: 6	Number of points in x direction: 100
Minimum	y: -34	Number of points in y direction: 100
Maximum	y: -28	Initial time:
Number of points in x	direction: 585	Final time: 91
Number of points in y	direction: 395	
Initial time	. 0	Advect Closed Diffusion Barriers and Create GIF
Final time	: 90	
Number of intermedia	te points	
for time averaging:	10	
Compute Ten	sor Field Data	
Or Upload Precomputed Ter	sor Field Data	
Browse File		
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Figure 1: Set of values used for the computation of the time-averaged Cauchy-Green strain tensor.

Once the computation is finished, the results may be found in the file "TensorFieldData.mat" inside the folder "Output". This file can be used as input to the GUI in the field "Upload Precomputed Tensor Field Data" to avoid the computationally expensive task of re-computing the Cauchy-Green tensor field at a later time. The computational procedure to detect Elliptic Lagrangian Coherent Structures is exactly the same after the user has selected the "Elliptic Lagrangian Coherent Structures".

3 Closed Diffusion Barriers

Before being able to compute closed diffusion barriers, we need to specify the necessary integration options. These comprise the fields "Integration in the Physical Space" and "Step Size". The user may start with the default values and then experiment with them to extract larger structures. Finally, the GUI automatically detects the number of cores of the machine in which it is running and it sets the number of cores used for the computation to one less than that. Once these selections are made, we press the button "Compute Closed Diffusion Barriers".

4 Plots and Output

After the computation of closed diffusion barriers is completed, we press "Compute Outermost Closed Diffusion Barriers and Plot". This results in the creation of the files "NullGeodesics.fig" and "OutermostNullGeodesics.fig" in the folder "Output" containg all and the outermost extracted material diffusion barriers, respectively, both superimposed with the DBS field. The structures that we extracted using the values shown in Figure 1 are depicted in Figures 2 and 3. Finally, in the folder "Output" the file "OutermostNullGeodesics.mat" contains the x and y components of the outermost structures for post-processing.



Figure 2: Diffusion Barrier Strength field and Closed Diffusion Barriers for the values presented in Figure 1.



Figure 3: Diffusion Barrier Strength field and Outermost Closed Diffusion Barriers for the values presented in Figure 1.

5 Advection of Closed Diffusion Barriers

The last feature of the GUI showcases the comparison of time evolution of random tracers and the outermost material diffusion barriers. The tracers are placed in a uniform rectangular grid. In our example we used the values presented in Figure 4 for the rectangular grid and the time interval, respectively. The button "Advect Material Diffusion Barriers and Create GIF" creates the animation and saves it in the file "NullGeodesics.gif" inside the folder "Output".

	(Computation of Geodesic Transport Barriers
Detection N	lethod	Closed Diffusion Barriers
 Lagrangian Barriers 	 Eulerian Barrier 	s Integration Options
 Closed Diffusion Barriers 		Step Size: 0.01
Lower \mathcal{T}_0 value:	0.5	Number of Cores Used: 11
Upper \mathcal{T}_0 value:	2	Compute Closed Diffusion Barriers
Number of \mathcal{T}_0 values:	20	
O Elliptic Lagrangian Cohe	erent Structures	Plots and Output
Time Interval:	30	Compute Outermost Closed Diffusion Barriers and Plot
Lower λ value:	0.8	Compute Outermost Orosed Diritation Damers and Hot
Upper λ value:	1.2	Advection of Closed Diffusion Barriers
Number of A values.	20	Load Velocity Field
Averaged Diffusive Cauch	y-Green Tensor I	Field Minimum x: -4
	le diffusive met	Maximum x: 6
ocean_velocity_examp	ble_dinusive.mat	Minimum y: -34
Minimum x:	-4	Maximum y: -28
Maximum x:	6	Number of points in x direction: 100
Minimum y:	-34	Number of points in v direction: 100
Maximum y:	-28	
Numbers of a state to a state	E95	Initial time: 0
Number of points in x dir	ection: 585	Final time: 90
Number of points in y dir	ection: 395	Advect Closed Diffusion Barriers and Create GIF
Initial time:	0	
Final time:	90	
Number of intermediate for time averaging:	points 10	
Compute Tensor	Field Data	
Or Upload Precomputed Tenso	r Field Data	
Browse File		
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Tool		

Figure 4: Set of values used for the computation of the advection of Closed Diffusion Barriers.

6 Eulerian Barriers

In case of Eulerian Barriers, the computational procedure is almost the same as in the Lagrangian setting. The differences are highlighted in Figure 5. More specifically, following [3] included in the folder "doc", the corresponding tensor inherent to the underlying theory is the rate-of strain tensor. This tensor is not positive definite and thus, the admissible range of λ values is allowed to contain negative values. Finally, since it is a computation concerning the instantaneous limit of the Lagrangian setting, the user can only specify one time, namely, the initial time. The extracted Eulerian Barriers for the case presented in Figure 5 are depicted in Figure 6.

	Computation	of Geodesic Transport Barriers
Detection	Vethod	Objective Eulerian Barriers
O Lagrangian Barriers	 Eulerian Barriers 	Integration Options
		Interpolation in the Physical Space
O Diffusive Instantaneous Barriers		Step Size: 0.01
Lower \mathcal{T}_0 value:	0.5	Number of Cores Used: 11
Upper \mathcal{T}_0 value:	2	Compute Objective Eulerian Barriera
Number of \mathcal{T}_0 values:	20	
Objective Eulerian Bar	riers	Plots and Output
Time Interval:	30	Compute Order Mart Objective Evidence Register and Dist
Lower λ value:	-0.03	Compute Outenviost Objective Eulerian Barriers and Piot
Upper λ value:	0.03	Advertise of Objective Eulerice Device
Number of λ values:	20	Advection of Objective Eulerian Barriers
		Load Velocity Field
Rate-of-Strain Tensor Field		Minimum x: -4
		Maximum x: 6
ocean_velocity_exam	nple_diffusive.mat	Minimum y: -34
Minimum x:	-4	Maximum y: -28
Maximum x	6	Number of points in x direction: 100
Minimum y:	-34	Number of points in y direction: 100
Maximum y	-28	Initial time: 30
Number of points in x d	irection: 585	Final time: 35
Number of points in y d	irection: 395	
Initial time:	30	Advect Objective Eulerian Barriers and Create GIF
Final time:	91	
Number of intermediate for time averaging:	points 10	
Compute Tenso	r Field Data	
Or Upload Precomputed Tens	or Field Data	
Browse File		

Figure 5: Set of values used for the computation of the Eulerian Barriers.



Figure 6: Extracted Eulerian Barriers for the values presented in Figure 5.

References

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- [3] M. Serra & G. Haller, Objective Eulerian coherent structures. Chaos26 (2016).