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## bUnwarpJ: Consistent and Elastic Registration in ImageJ.

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#### Outline

User or developer? What can this plugin offer me? As user: Main features. Parameters. Results. As developer: Flow chart. Optimizer. Future work? Extensions?

## **bUnwarpJ** for users

(if you dare...)

#### **Consistent and elastic registration**



### The plugin: main features



## Image and deformation representation: cubic B-splines

- Multi-resolution approach
- Spline deformation
- Spline interpolation
- Vectorial splines







## So, what is the deformation precision?

Multi-resolution: from "Very coarse" to "Super Fine".
 Meaning: from 2<sup>o</sup> x 2<sup>o</sup> = 1x1 intervals of B-spline coefficients to 2<sup>4</sup> x 2<sup>4</sup> = 16x16 intervals.

Basically, more B-spline coefficients, more details.







- Image similarity: MSE Mean Square Error (grayscale pixel value)
- Landmarks: geometric error between landmark points.
- Regularization: divergence and curl of the deformations.
- Consistency: geometric distances between the pixel coordinates after applying both transformations (direct and inverse).

## Weights: similarity and landmarks

#### Similarity:

difference between pixel values. Weight: 1.0 usually enough.

 Landmarks: distance between manual landmark points. Weight: 1.0 (if any).





#### Weights: regularization

- The regularization weights penalize the divergence and curl of the vector field.
- Meaning: we penalize vector fields with many points like this:



Result: we force the deformation to be smooth.
Weights: 0.1 and 0.1 when there's no prior knowledge about the deformation shape.

### Weights: consistency

- How invertible are the deformations?
- Weights: 10-30 are usually stable values.
- Advice: play around!



#### Similarity-Consistency

#### The toolbar



### **Results information (1)**



Basic

"Verbose" option checked

### **Results information (2)**

- If the "Verbose" option is checked, then every step of the optimization process is displayed.
- The "Stop Threshold" is the difference between these steps that forces the program to end.
- The optimal error values are displayed at the end of the process.

🍝 Result	is 🕘	
File Ed	dit Font	
Consis	tency Error (t–s): 5.6788949347	29587
f(35)=35	2.5629573468675 lambda=10(	00.0
Accepte	d	
Image	error (s-t): 187.82036833	612278
Image	error (t–s): 153.71636048	888152
Consis	tency Error (s-t): 5.4239806040	)519785
Consis	tency Error (t-s): 5.6728416480	041162
f(36)=35	2.6335510770974 lambda=100	0.0
Image	error (s-t): 187.69395849	6934
Image	error (t-s): 153.75317165	893526
Consis	tency Error (s-t): 5.4287950537	83524
Consis	tency Error (t-s): 5.6772708972	246117
f(37)=35	2.55319610689884 lambda=10	000.0
Optimal	direct similarity error = 187.693	3958496934
Optimal	inverse similarity error = 153.75	5317165893526
Optimal	direct consistency error = 0.542	8795053783524
Optimal	inverse consistency error = 0.56	\$77270897246117
2		

# Other relevant features for users

Since version 2.0 (August 29<sup>th</sup>, 2008), bUnwarpJ is fully compatible with ImageJ macro language. Example:

consistency\_weight=10 stop\_threshold=0.01 verbose save\_transformations");

- bUnwarpJ can be called from command line (no GUI).
- Color images are processed in grayscale and the resulting deformations are applied to the RGB channels.
- No, there is no such a thing as bUnwarpJ 3D (yet).

bUnwarpJ for developers

(if you dare...)

#### **Flow chart**



The initial deformations are the affine transformations between landmarks if they exist or the Identity if they don't.

#### **Optimization**



#### **Optimizer steps**

- It starts at the lowest resolution of both pyramids.
- It increases first the deformation detail.
- When the level optimum is found, it moves up in the other pyramid.



## Results Only Elastic

#### Direct

#### Inverse



Consistent

Source







### Results (2)

- Especially useful for serial images of broken, torn or folded tissue.
- Example: TEM sections of Lamina tissue from Drosophila Melanogaster.





#### Images by courtesy of Marta Rivera-Alba

#### SIFT and MOPS plugins support

 Automatic landmarks introduced thanks to Stephan Saalfeld's plugin.

 Don't miss next talk ;-)



### Future work (any volunteer?)

#### Extension to 3D images:

- Complexity.
- Visualization?
- Open source alternatives: Elastix, ITK?
- Change similarity metric, mutual information?Detailed manual.

![](_page_23_Picture_0.jpeg)