### BIP: Biological Image Processing

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## Why BIP

- Originally developed as an internal tool in the team for integrating, interfacing and sharing our developments in image processing and analysis
- ▶ Batch processing with easy, flexible specification and selection of images to be processed, without having to modify a script or a macro
- By-pass some constraints and limitations frequently encountered with existing tools (e.g., related to image structure, numerical types, computing time, etc.)
- Specifying and running possibly complex sequences of image processing operations (pipelines) with a minimal, as-simple-as-possible syntax
- Need to deploy seamlessly on HPC servers



```
### The properties of the prop
```





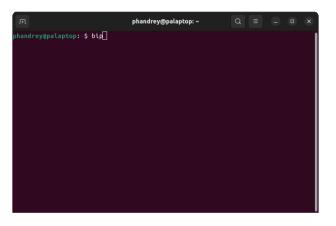
### low-level APIs



### integrated GUIs



### BIP user interface



## Batch processing with BIP



### Processing one image

```
shell$ bip median-filter ball 3 image.tif
```

### Processing several images

```
shell$ bip median-filter ball 3 image1.tif image2.tif ... imageN.tif
```

### Short-cut using shell wildcards

```
shell$ bip median-filter ball 3 image*.tif
```

## Iteration and selection without iteration and selection



Assuming a standardized file nomenclature (e.g., ISO8601 for dates) is used:

▶ Processing all DAPI images...

```
shell$ bip median-filter ball 3 image*dapi*.tif
```

...acquired between years 2015 and 2019...

```
shell$ bip median-filter ball 3 image-201[5-9]*dapi*.tif
```

... either in October or November

```
shell$ bip median-filter ball 3 image-201[5-9]-1[01]*dapi*.tif
```

### Image dimensions and numerical types



### 127 image types in total:

- 2 or 3-dimensional space
- mono- or multi-channels
- mono- or multi-timepoints
- scalar or vector values

Туре	Min	Max	IJ/Fiji
uint8	0	255	8 bits
int8	-128	127	
uint16	0	65535	16 bits
int16	-32768	32767	
uint32	0	4,294,967,295	
int32	-2,147,483,648	2,147,483,647	
float	-3.4e + 38	3.4e + 38	32 bits
double	-1.8e+304	1.8e+304	

BIP operators transparently supports all image dimensions and numerical types

### shell\$ bip info \*.tif

	A	В	С	D	Е	F	G	н	1	J	K	L	М
1	file	type	compression	sizeX	sizeY	sizeZ	samples	timepoints	channels	dx	dy	dz	unit
2	A04_WT_M12_T00h_iso.tif	uint32	Izw	1024	1024	267	1	1	. 1	0.181818	0.181818	0.181818	μm
3	A04_WT_M12_T03h_iso.tif	uint32	Izw	1024	1024	272	1	1	. 1	0.181818	0.181818	0.181818	μm
4	A04_WT_M12_T06h_iso.tif	uint32	lzw	1024	1024	261	1	1	. 1	0.181818	0.181818	0.181818	μm
5	A04_WT_M12_T09h_iso.tif	uint32	Izw	1024	1024	264	1	1	. 1	0.181818	0.181818	0.181818	μm
6	A04_WT_M12_T12h_iso.tif	uint32	Izw	1024	1024	228	1	1	. 1	0.181818	0.181818	0.181818	μm
7	A05_WT_M09_T00h_iso.tif	uint32	lzw	1024	1024	267	1	1	. 1	0.181818	0.181818	0.181818	μm
8	A05_WT_M09_T03h_iso.tif	uint32	lzw	1024	1024	264	1	1	. 1	0.181818	0.181818	0.181818	μm
9	A05_WT_M09_T06h_iso.tif	uint32	lzw	1024	1024	248	1	1	. 1	0.181818	0.181818	0.181818	μm
10	A05_WT_M09_T09h_iso.tif	uint32	Izw	1024	1024	267	1	1	1	0.181818	0.181818	0.181818	μm
11	A05_WT_M09_T12h_iso.tif	uint32	lzw	1024	1024	259	1	1	. 1	0.181818	0.181818	0.181818	μm
12	A05_WT_M10_T00h_iso.tif	uint32	lzw	1024	1024	272	1	1	. 1	0.181818	0.181818	0.181818	μm
13	A05_WT_M10_T03h_iso.tif	uint32	Izw	1024	1024	270	1	1	1	0.181818	0.181818	0.181818	μm
14	A05_WT_M10_T06h_iso.tif	uint32	lzw	1024	1024	264	1	1	1	0.181818	0.181818	0.181818	μm
15	A05_WT_M10_T09h_iso.tif	uint32	lzw	1024	1024	272	1	1	. 1	0.181818	0.181818	0.181818	μm
16	A05_WT_M10_T12h_iso.tif	uint32	Izw	1024	1024	272	1	1	. 1	0.181818	0.181818	0.181818	μm
17	A07_WT_M01_T00h_iso.tif	uint32	lzw	1024	1024	270	1	1	1	0.181818	0.181818	0.181818	μm
18	A07_WT_M01_T03h_iso.tif	uint32	lzw	1024	1024	253	1	1	. 1	0.181818	0.181818	0.181818	μm
19	A07_WT_M01_T06h_iso.tif	uint32	lzw	1024	1024	261	1	1	. 1	0.181818	0.181818	0.181818	μm
20	A07_WT_M01_T09h_iso.tif	uint32	lzw	1024	1024	259	1	1	1	0.181818	0.181818	0.181818	μm
21	A07_WT_M01_T12h_iso.tif	uint32	lzw	1024	1024	270	1	1	1	0.181818	0.181818	0.181818	μm
22	A07_WT_M02_T00h_iso.tif	uint32	lzw	1024	1024	248	1	1	. 1	0.181818	0.181818	0.181818	μm
23	A07_WT_M02_T03h_iso.tif	uint32	Izw	1024	1024	259	1	1	. 1	0.181818	0.181818	0.181818	μm
24	A07_WT_M02_T06h_iso.tif	uint32	Izw	1024	1024	248	1	1	1	0.181818	0.181818	0.181818	μm
25	A07_WT_M02_T09h_iso.tif	uint32	lzw	1024	1024	242	1	1	. 1	0.181818	0.181818	0.181818	μm
26	A07_WT_M02_T12h_iso.tif	uint32	lzw	1024	1024	256	1	1	1	0.181818	0.181818	0.181818	μm
27	A07_WT_M03_T00h_iso.tif	uint32	lzw	1024	1024	289	1	1	1	0.181818	0.181818	0.181818	μm

## Some basic yet useful operators

Conversion between numerical types (safe mode)

```
shell$ bip convert uint16 *.tif
```

File compression (lossless LZW compression)

```
shell$ bip compress ../segmented/*.tif
```

Resampling 3D images into (quasi-)cubic voxels

```
shell$ bip isoscale linear ../acquired/*.tif
```

## Image analysis in batch







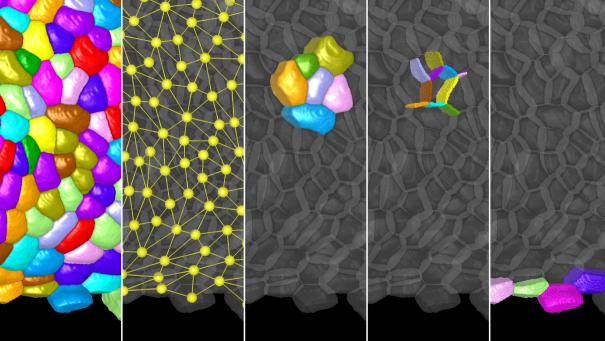






shell\$ bip region-analysis -p size,shape \*.tif

1	file	label	count	volume	elongation	flatness	sphericity	equiv-radius	surface-area	globularity
594	A04_WT_M12_T00h_iso.tif	3289	705	4.23742	1.84963	1.59787	0.477165	1.00385	16.2055	0.782503
595	A04_WT_M12_T00h_iso.tif	3300	24594	147.823	1.45082	1.29395	0.59097	3.28008	161.11	0.911705
596	A04_WT_M12_T00h_iso.tif	3301	19751	118.714	1.35756	1.22138	0.648865	3.04886	134.927	0.922721
597	A04_WT_M12_T00h_iso.tif	3304	26489	159.213	1.45414	1.27048	0.657971	3.36225	163.33	0.91745
598	A04_WT_M12_T00h_iso.tif	3322	19992	120.162	1.25007	1.01886	0.759263	3.06121	129.082	0.973366
599	A04_WT_M12_T00h_iso.tif	3330	21510	129.286	1.21145	1.34529	0.663483	3.13681	141.767	0.931793
600	A04_WT_M12_T00h_iso.tif	3337	28668	172.31	1.58923	1.33064	0.588998	3.45202	178.643	0.883869
601	A04_WT_M12_T00h_iso.tif	3340	12686	76.2494	1.39073	1.02883	0.672328	2.63057	99.2616	0.944561
602	A04_WT_M12_T00h_iso.tif	3346	15638	93.9925	1.34673	1.17444	0.759587	2.82056	109.569	0.955033
603	A05_WT_M09_T00h_iso.tif	13	31817	191.237	1.46181	1.26962	0.634412	3.57405	186.813	0.909885
604	A05_WT_M09_T00h_iso.tif	15	29752	178.825	1.03968	1.07454	0.732095	3.49499	170.313	0.973479
605	A05_WT_M09_T00h_iso.tif	16	31851	191.441	1.24185	1.2874	0.701868	3.57532	180.754	0.944743
606	A05_WT_M09_T00h_iso.tif	17	24193	145.412	1.12795	1.35482	0.677676	3.26215	152.245	0.951495
607	A05_WT_M09_T00h_iso.tif	19	28551	171.606	1.1406	1.23409	0.755773	3.44732	163.949	0.960961
608	A05_WT_M09_T00h_iso.tif	20	24877	149.524	1.11867	1.48876	0.707009	3.29261	152.926	0.941242
609	A05_WT_M09_T00h_iso.tif	23	24065	144.643	1.07933	1.32058	0.733488	3.25639	147.758	0.961438



## Overview of BIP operators

### **Operations**

- type conversions
- (de)compression - channels & slices
- image arithmetics
- geom. transforms

### Filtering

- linear filters
- non-linear filters
- edge-preserving filters
- contrast enhancement
- Fourier transform, xcorr

### Spatial statistics

- summary descriptors
- model sampling
- model testing
- several models

# Mathematical morphology

- binary & grayscale
- morphological filters
- attribute (size) filters
- reconstruction ops.
- extrema filtering

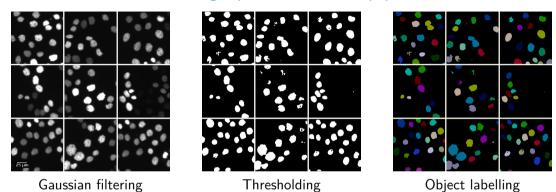
### Measurements

- geometrical analysis
- topological analysis
- intensity analysis
- distance maps
- parametric maps
- object contacts

### Segmentation

- thresholding operators
- component labelling
- watersheds
- gradient operators

## Assembling operations into pipelines



```
shell$ bip gaussian-filter 1.0 nuclei*.tif
shell$ bip otsu-thresholding nuclei*gaussian*.tif
shell$ bip labelling nuclei*otsu*.tif
```

## Pipeline processing with BIP



### Define the pipeline in a text file (e.g., process.bip)

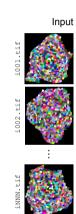
```
gaussian-filter 1.0
otsu-thresholding
labelling
```

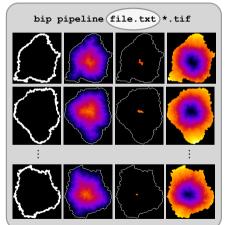
### Run the pipeline

```
shell$ bip pipeline process.bip nuclei*.tif
```

### file.txt

store \$image
select-fringe
store \$fringe
recall \$image
cell-distance \$fringe
select max
threshold 1
store \$center
recall \$image
cell-distance \$center





### Output

file	label	distance
i001.tif	13	0
i001.tif	15	0
i001.tif	16	1
i001.tif	17	1
i001.tif	19	2
i001.tif	20	1
i001.tif	23	2
i001.tif	24	1
i001.tif	30	1
i001.tif	31	1
i001.tif	32	3
i001.tif	33	0
i001.tif	37	2
i001.tif	38	1
i001.tif	39	3
i001.tif	41	4
i001.tif	42	3
÷	÷	:

## BIP pipelines in the fast lane



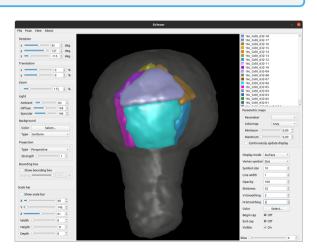
```
shell$ bip pipeline -e "gaussian-filter 1.0 | otsu | labelling" *.tif
```

### Extraction and visualization of 3D meshes

shell\$ bip export-shapes embryo.tif





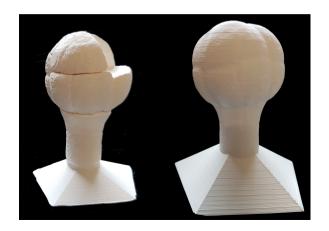


## Exporting meshes for 3D printing

shell\$ bip export-shapes --stl embryo.tif

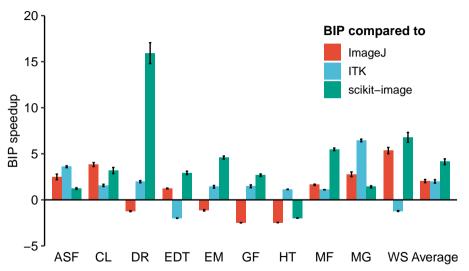






## Benchmarking BIP

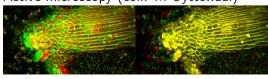




### Chemical screen (coll. R Kumar)

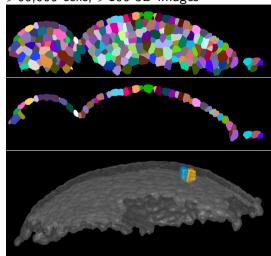
> 20,000 2D images

Active microscopy (coll. M Uyttewaal)

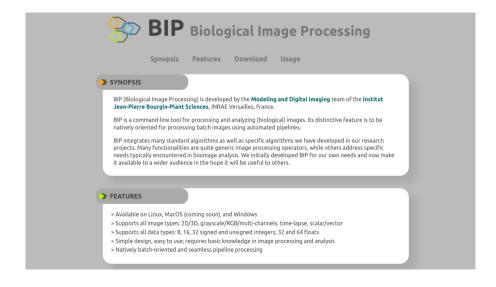


## $\mathsf{SAM}\ \mathsf{time\text{-}lapses}\ \mathsf{(coll.}\ \mathsf{D}\ \mathsf{Bouchez})$

>60,000 cells, >100 3D images



### https://andreylab.versailles.inrae.fr/html/bip.html



natively designed for batch processing

unified basic, pipeline and HPC uses

data and algorithms are completely separated

original niche in the bioimage informatics ecosystem

shell\$ bip thank-you

