

Lineage Tracer :: Documentation

Requirements

Lineage Tracer requires several tools:

- Imaris:
 - ImarisXT (IPSS)
 - Imaris MeasurementPro (Reference Frame)
 - Imaris Track
 - Imaris Lineage
- MATLAB:
 - IceImarisConnector: <https://github.com/aarpon/IceImarisConnector>

For the (optional) tree validation, the following is required:

- Python 2.7:
 - pIceImarisConnector: <https://github.com/aarpon/pIceImarisConnector/releases/latest>
 - Zhang-Shasha Tree edit distance (<https://zhang-shasha.readthedocs.io/en/latest/>):
`python -m pip install zss`
 - treelib: `python -m pip install treelib`
 - numpy: `python -m pip install numpy`
 - scipy: `python -m pip install scipy`

Usage

Cell segmetation

- Detect green and red cells using the **Spot detector** in Imaris. Use a low threshold to segment all cells even at the cost of including spurious spots. Allow spot radius to be adapted to more accurately fit the volume of the segmented cell. Bright but very small spots can easily be filtered out during segmentation.

First validation

Using the “BSSE > Lineage Tracer > Validate cells in embryo” ImarisXTension (MATLAB)

- Use the green spot positions to estimate the embryo diameter and discard green spots that are likely to be outside of the embryo. The radius of the embryo is roughly estimated as the median of all maximal inter-spot distances.

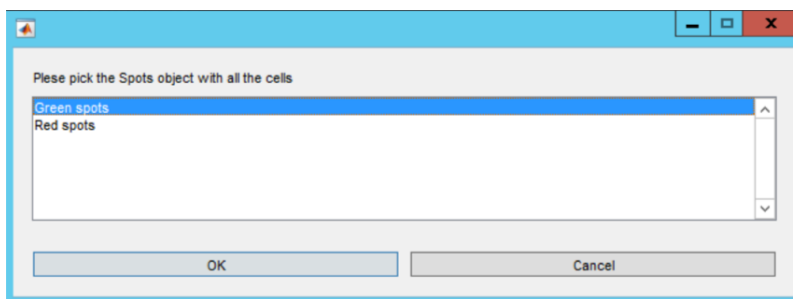


Figure 1: Select the green cells

- Search for spots that occur within a small defined distance from a spot in the same channel, discard all wrongly segmented double spots on one nucleus and replace them by one new spot.

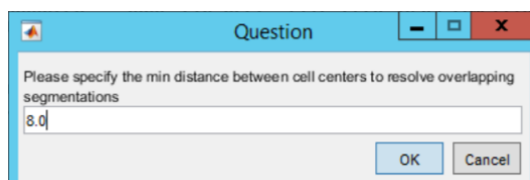


Figure 2: Resolve double segmentations

- A user-defined multiplicative factor can optionally compensate for estimation errors and prevent cells at the boundary of the embryo to be discarded should this constraint be too stringent.

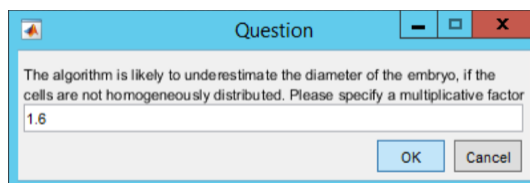


Figure 3: Correct for underestimation of embryo diameter

- Discard all spurious red spots that do not colocalize with a green spot. Note that due to the equilibrium between protonated and de-protonated chromophore, green to red photoconversion of pcFPs is never exhaustive and will always retain a green population, rendering this quality control step possible.

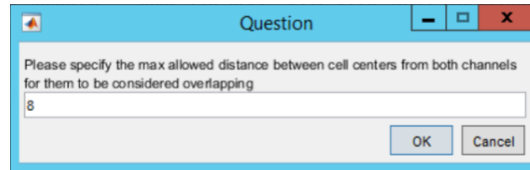


Figure 4: Remove red spots that do not overlap with green spots

- A red spot discarded during the first validation can optionally be recovered if there is a valid red spot in previous time point within a user-defined search radius. This adjustment compensates for remaining miss-segmentations in the green channel.

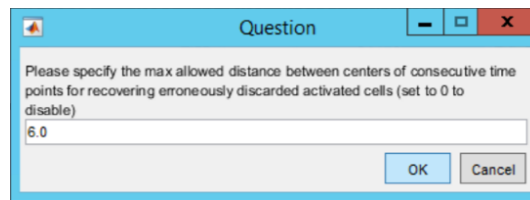


Figure 5: Recover discarded red spots

Embryo alignment (drift and rotational correction) / Cropping

Using the “BSSE > Lineage Tracer > Set reference frames from cells” ImarisXTension (MATLAB)

- Imaris Reference Frame Objects are created in MATLAB for each time point: their origin is set at the position of the center of mass (COM) of the green spots and their orientation is given by the vector.

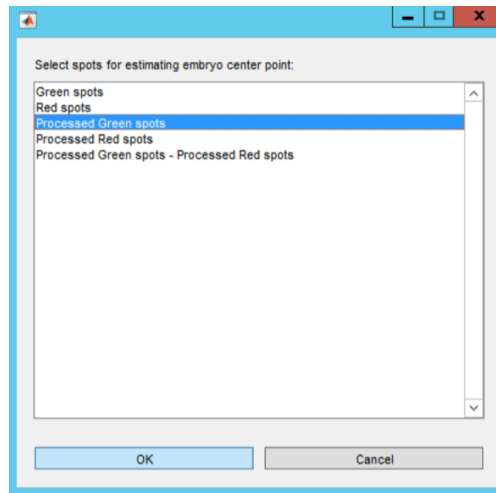


Figure 6: Select processed green spots

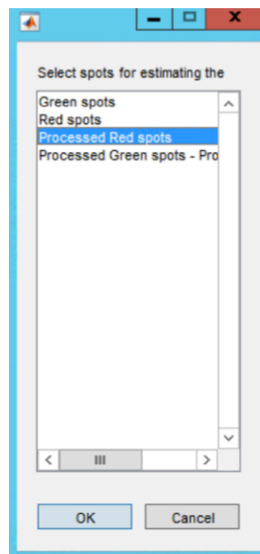


Figure 7: Select processed red spots

- Perform resampling using the reference frame object in Imaris.

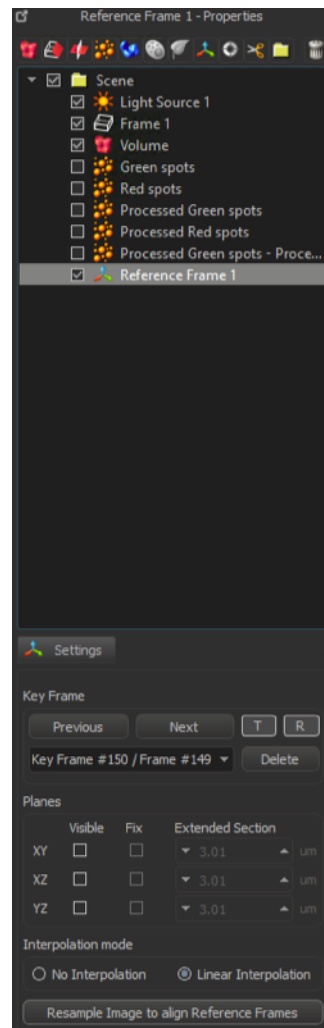


Figure 8: Select created reference frame in Imaris

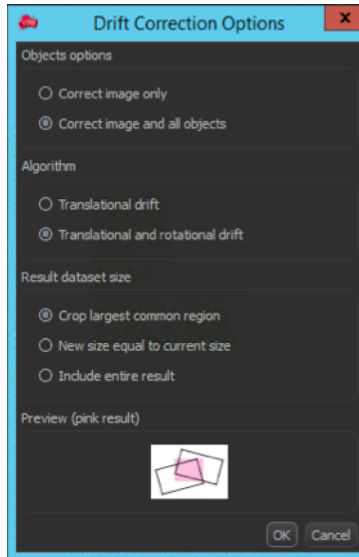


Figure 9: Perform registration

Using the “BSSE > Lineage Tracer > Correct rotation around reference frame axis” ImarisXTension (MATLAB)

- The previous correction still has one degree of freedom. The rotation angle around the reference frame axis is obtained by comparing the positions of the green spots at timepoints t and $t - 1$ over 360 1-degree rotations and by choosing the angle that minimizes the cell drift between time points.

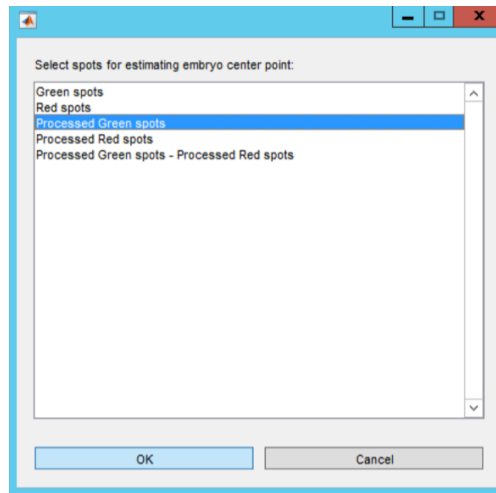


Figure 10: Select the processed green spot

- Perform resampling using the reference frame object in Imaris and crop the result to the smallest bounding volume.

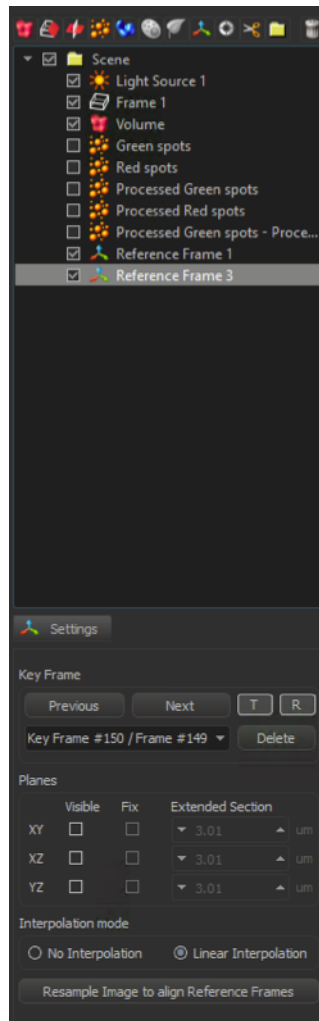


Figure 11: Select created reference frame in Imaris

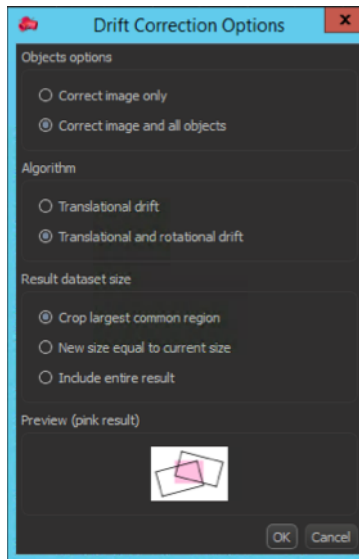


Figure 12: Perform registration

Second validation and subsetting

Using the “BSSE > Lineage Tracer > Validate cells in embryo”
ImarisXTension (MATLAB)

- To pick up red cells that were not recovered previously, re-run the first validation on the re-aligned embryo (follow the steps from above).
- Create a new spot object that contains the subset of green cells that do not colocalize with red cells.

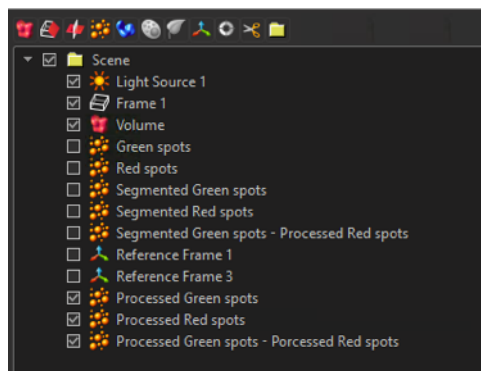


Figure 13: Subsetting

Lineage tree reconstruction

- Imaris' Lineage module is used to track the cells over time and reconstruct their lineage tree. The subsetting in the previous step allows us to reduce the complexity of the lineage tracing problem by breaking it down into two simpler, computationally less expansive, disjoint problems.

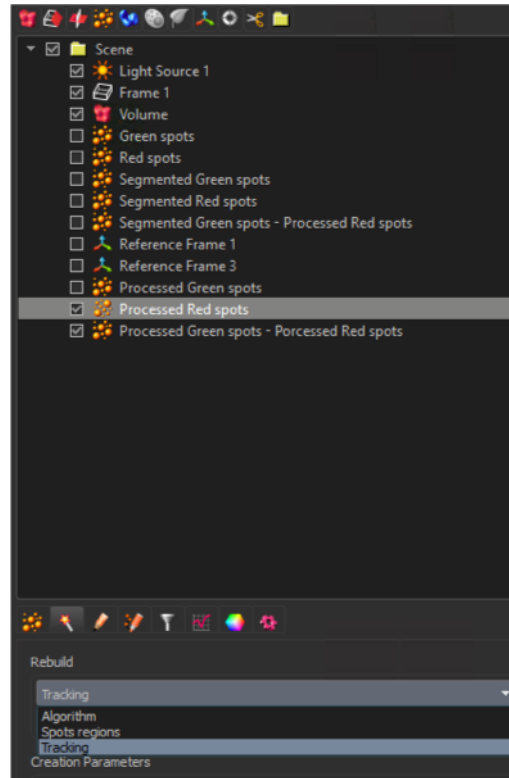


Figure 14: Lineage tree reconstruction

Comparative Analysis of lineage trees (optional)

Using the “BSSE > Lineage Tracer > Calculate total distance between lineage trees” ImarisXTension (python)

- Run the python XTension to calculate the total distance between lineage trees before and after correction.

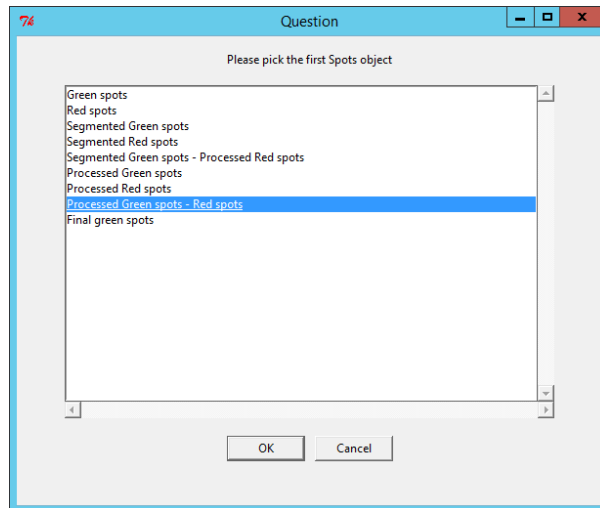


Figure 15: First lineage tree

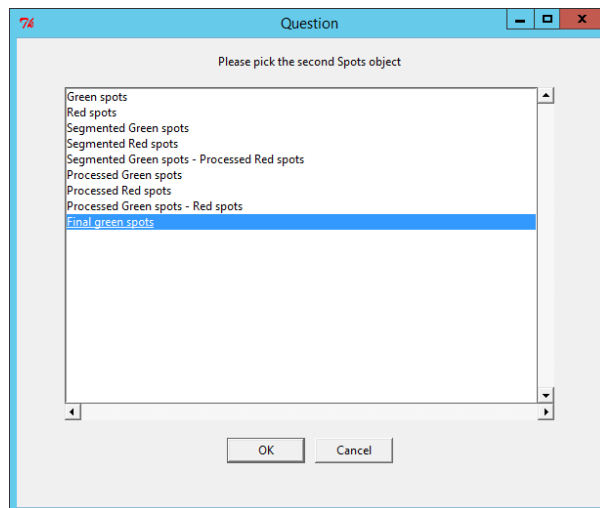
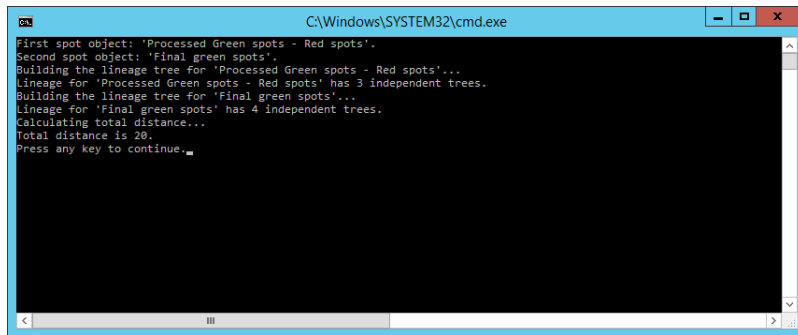


Figure 16: Second lineage tree



```
C:\Windows\SYSTEM32\cmd.exe
First spot object: 'Processed Green spots - Red spots'.
Second spot object: 'Final green spots'.
Building the lineage tree for 'Processed Green spots - Red spots'...
Lineage for 'Processed Green spots - Red spots' has 3 independent trees.
Building the lineage tree for 'Final green spots'...
Lineage for 'Final green spots' has 4 independent trees.
Calculating total distance...
Total distance is 20.
Press any key to continue.
```

Figure 17: Output of the lineage tree distance calculation