Microtubule segmentation on photofluorescent microphotography

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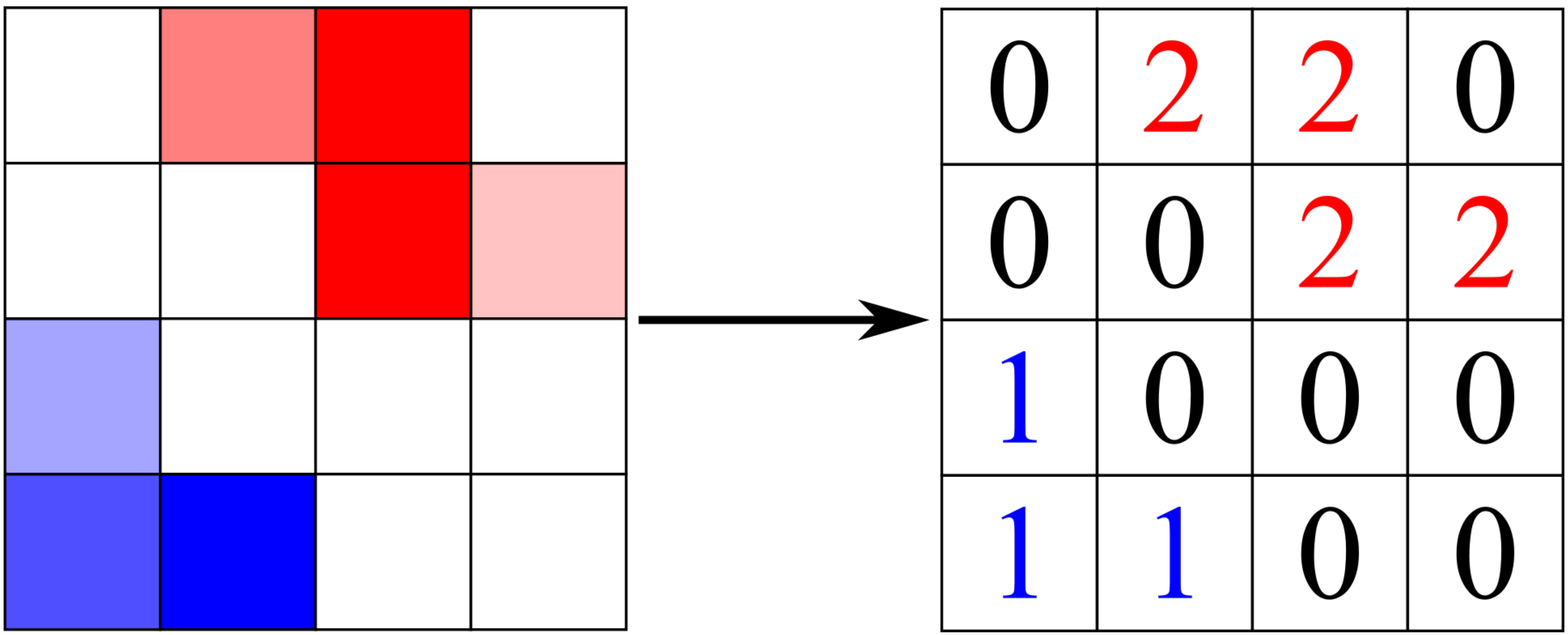
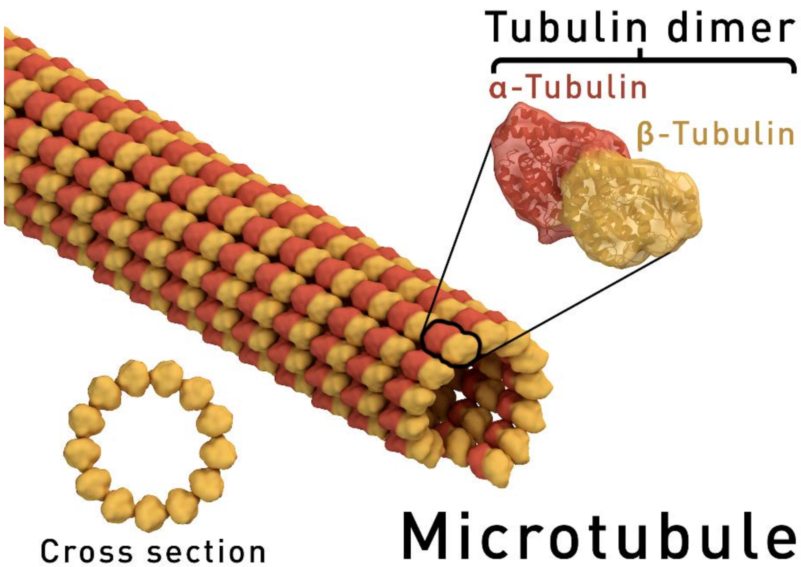
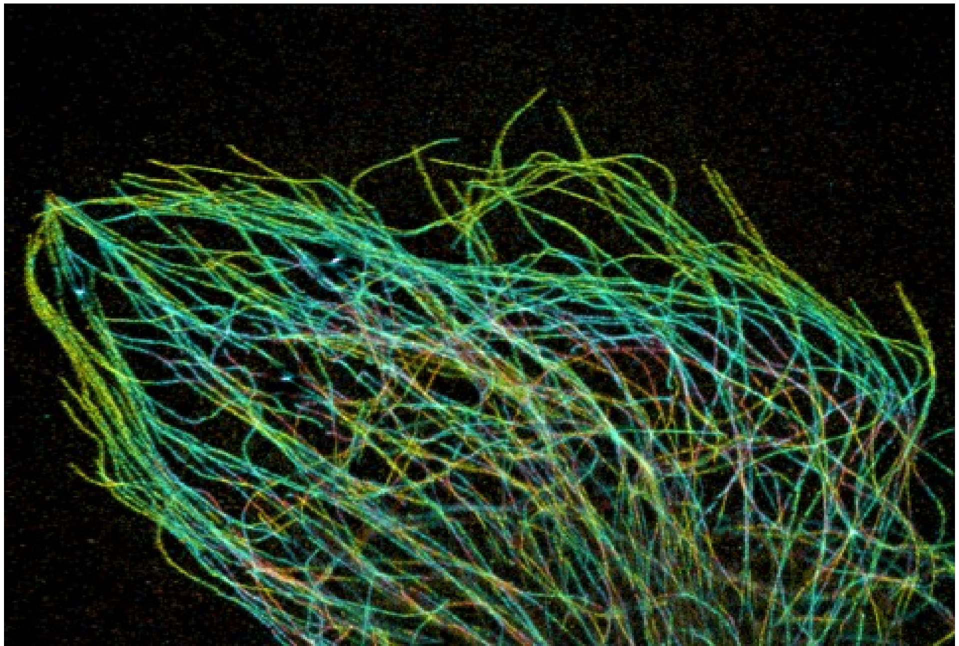
Image segmentation



Segmentation is the process of partitioning an image into multiple segments.

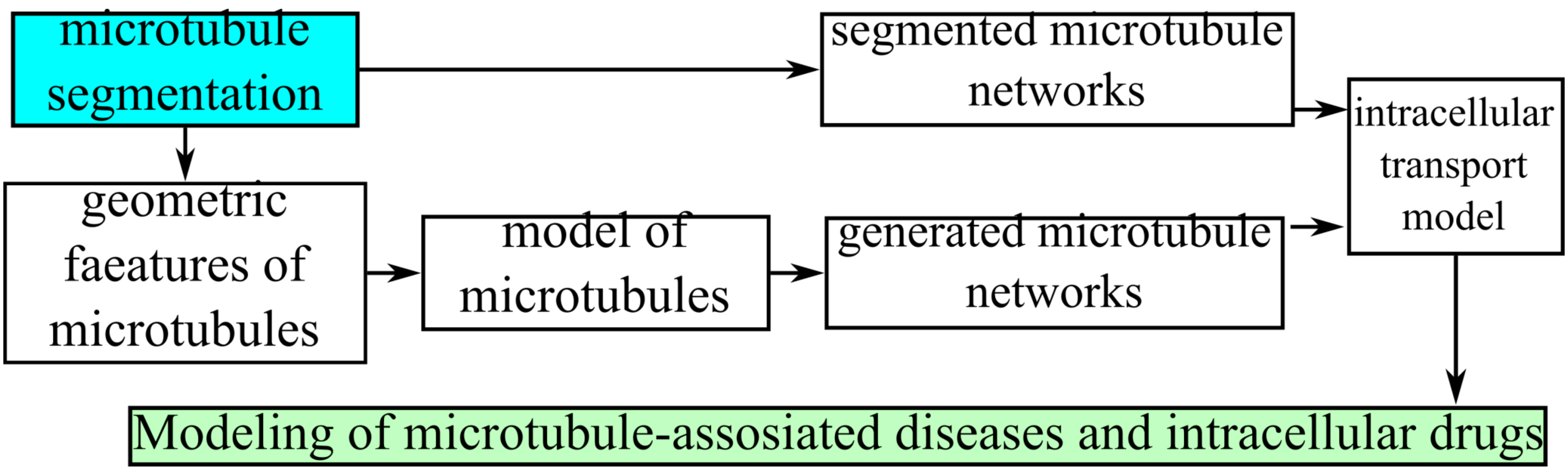
Microtubule network





Functions:
- **intracellular transport**
- cell structure maintaining
- cell division
- cilia and flagella functioning

Motivation



microtubule segmentation
segmented microtubule networks
intracellular transport model
geometric faeatures of microtubules
model of microtubules
generated microtubule networks
Modeling of microtubule-assosiated diseases and intracellular drugs

Microtubule segmentation specificity

1. Microtubules are thinner then they look on photofluorescent images

Photo

Real width

Microtubule segmentation specificity

1. Microtubules are thinner then they look on photofluorescent images

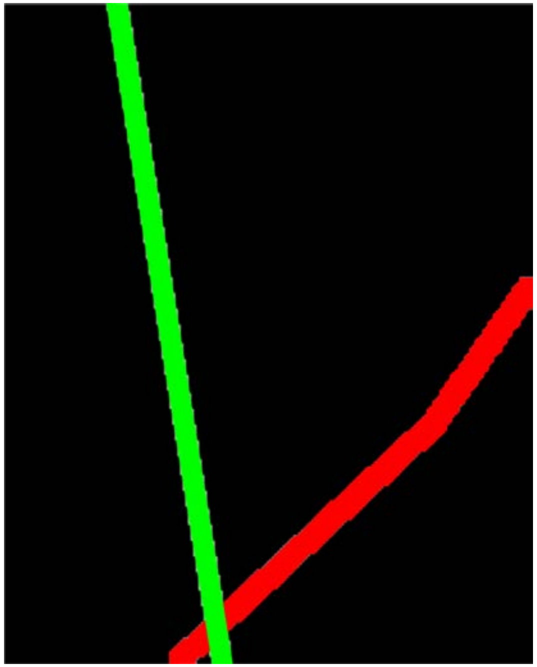
Photo

Microtubule segmentation special aspects

2. Each microtubule is a separate structure

Binary mask

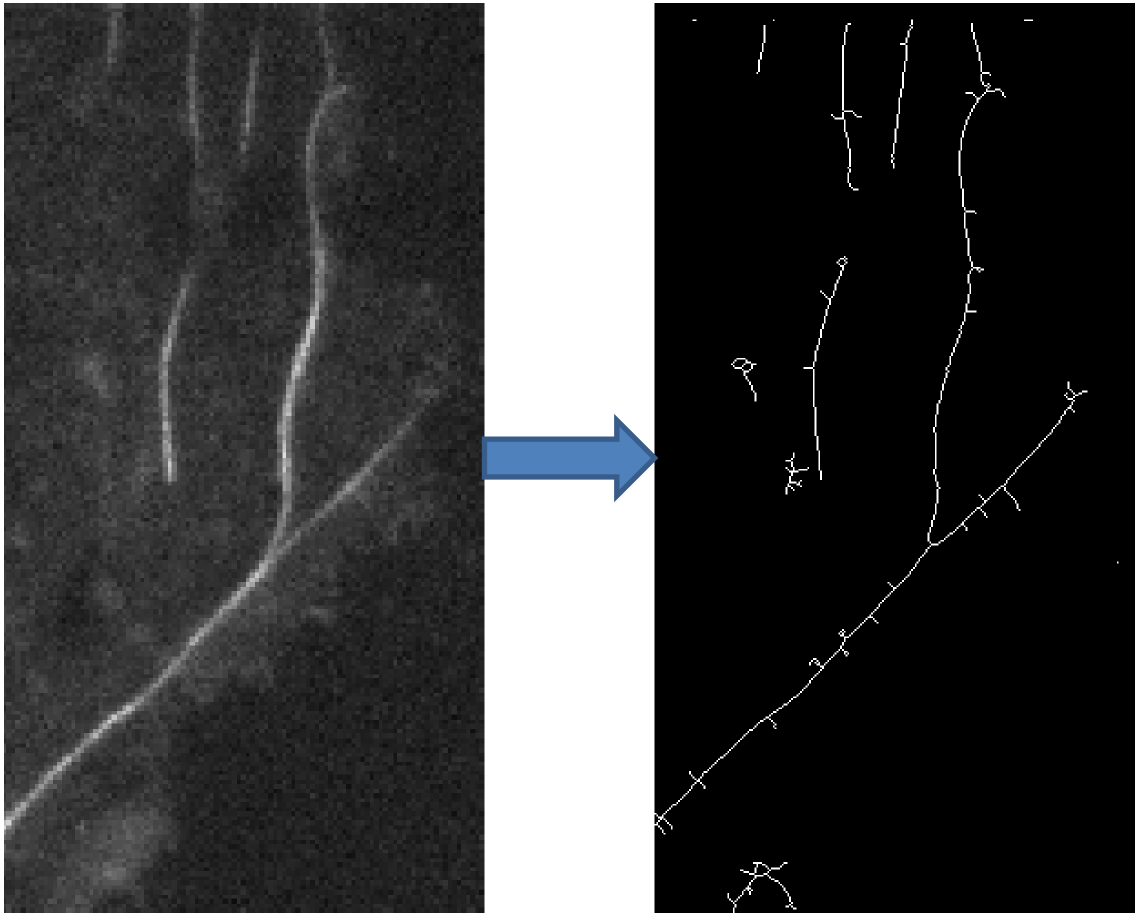
Separate mask for
Each microtubule



Segmentation algorithm

1. Preliminary segmentation
2. Graph construction
3. Separate segment segmentation
4. Segment combining

Getting binary mask



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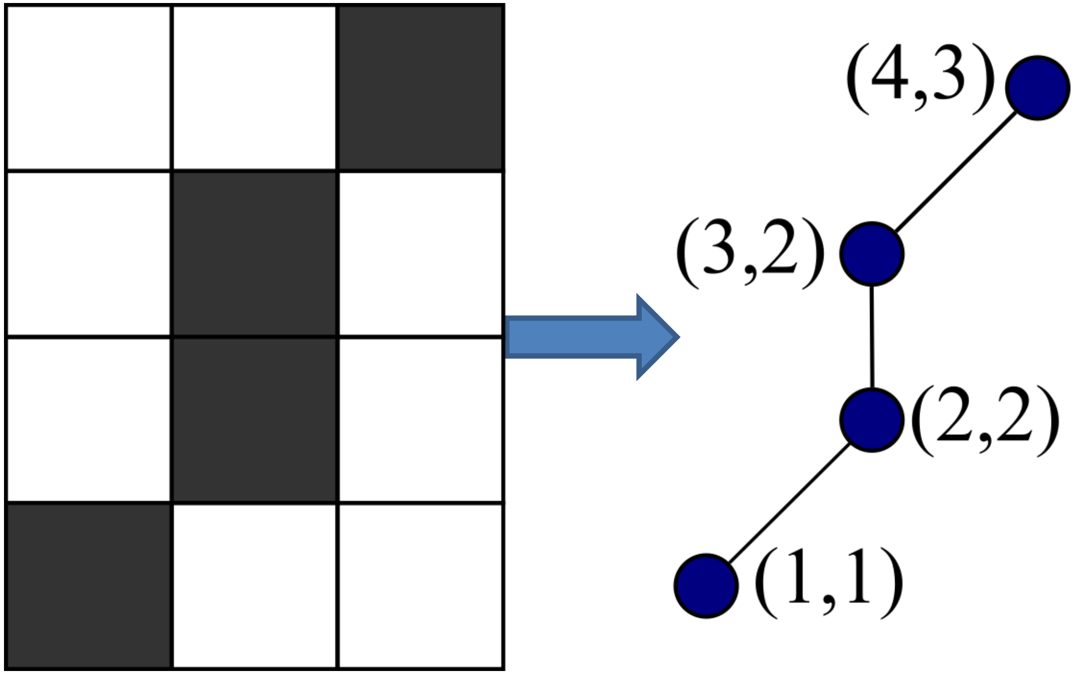
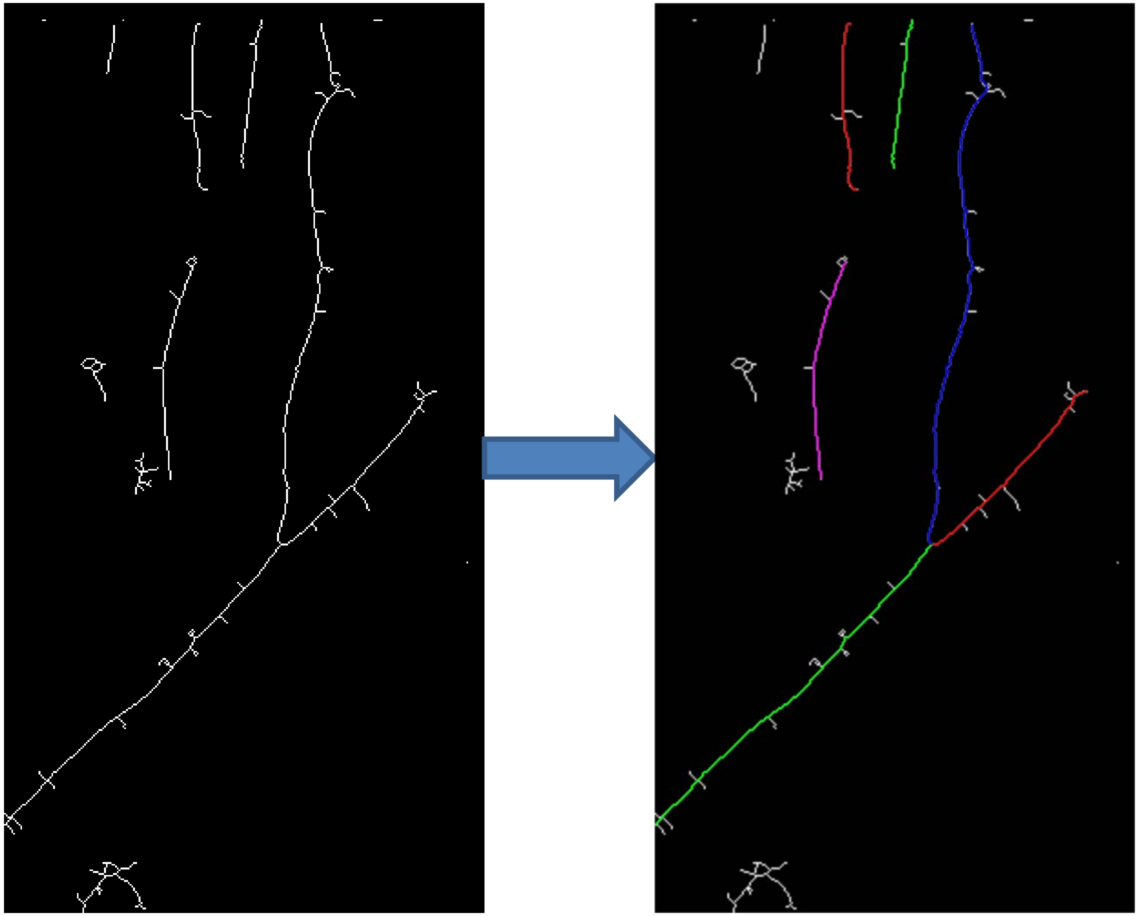
Transforming the binary mask into a graph



Segmentation algorithm

1. Preliminary segmentation
2. Graph construction
3. **Separate segment segmentation**
4. Segment combining

Using graph path search algorithms we find separate segments of microtubules



Segmentation algorithm

1. Preliminary segmentation
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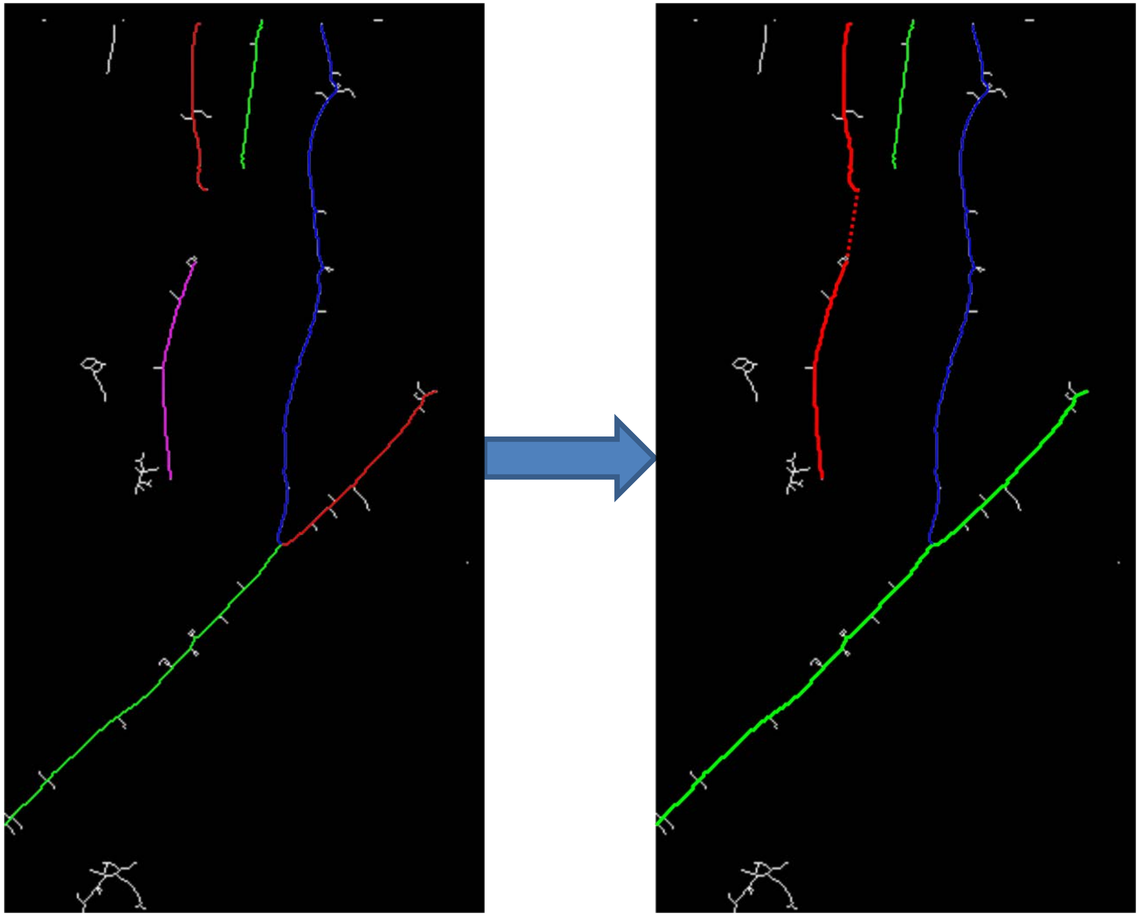
Combining of separate microtubule segments into one microtubule

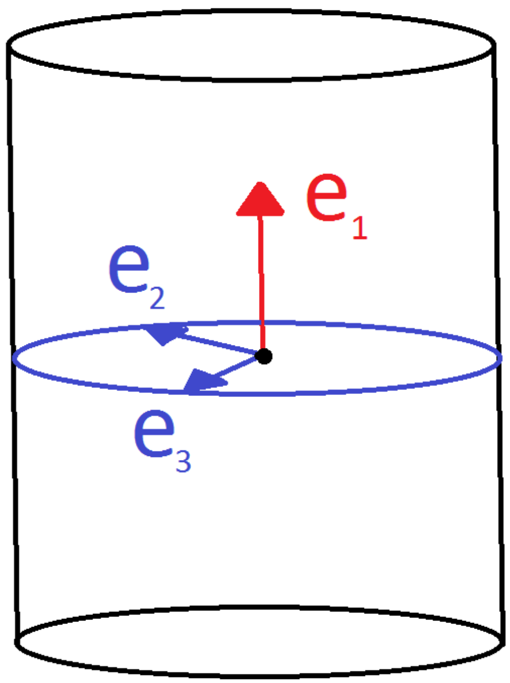


Frangi Vesselness filter

Tube model

For an ideal bright tube Hessian eigenvalues $\lambda_1\ \lambda_2\ \lambda_3$ and corresponding eigenvectors e_1, e_2, e_3 have the following properties:

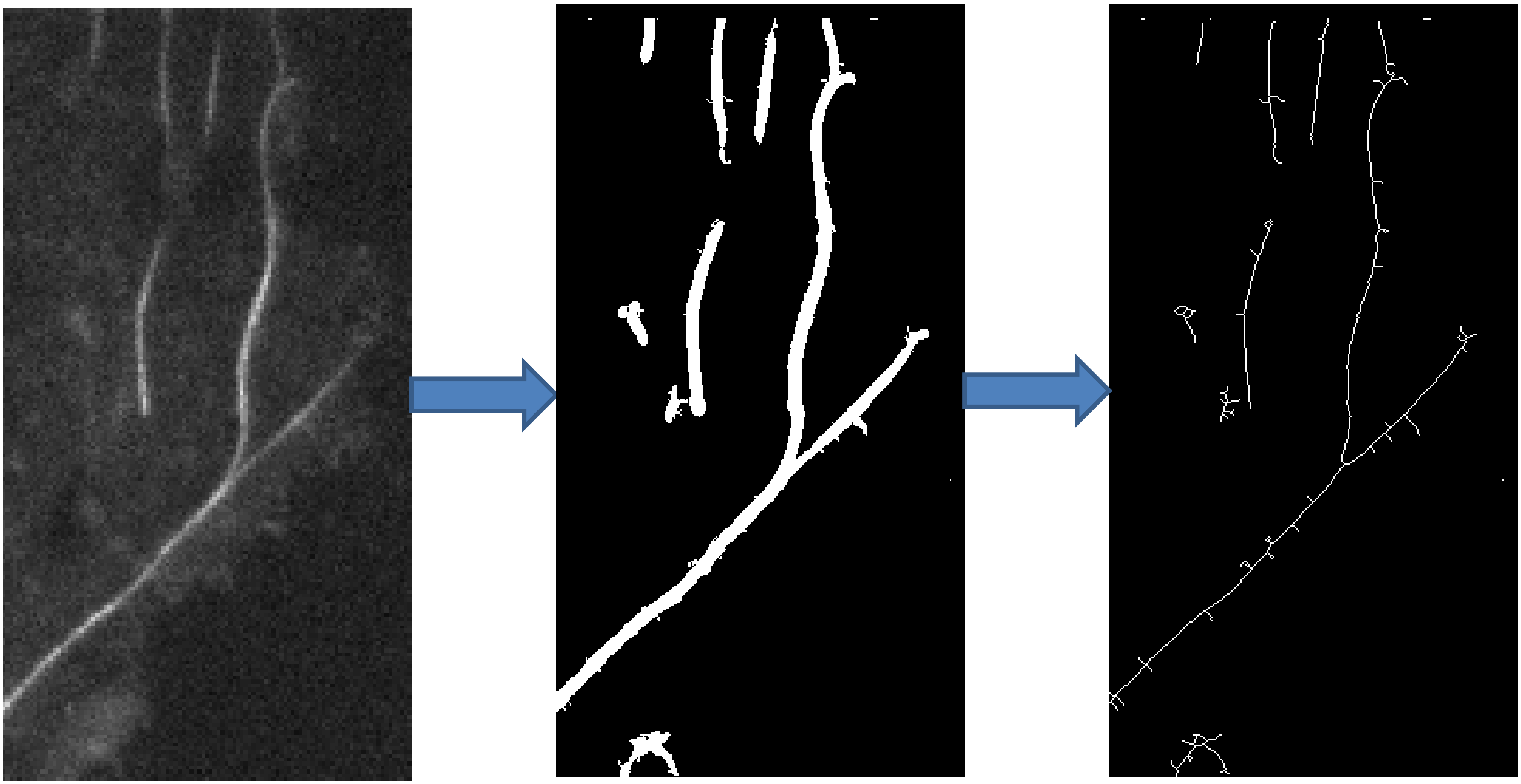
- $|\lambda_1| \ll |\lambda_2| \leq |\lambda_3|$
- e_1 directs along tube centerline
- e_2 and e_3 span the cross-section plane



[Frangi A. [et al.] Multiscale vessel enhancement filtering. Medical Image Computing and Computer-Assisted Intervention – MICCAI'98 – 1998. – P. 130-137.]

1. Preliminary segmentation

1. Frangi filter 2. Morphological thinning



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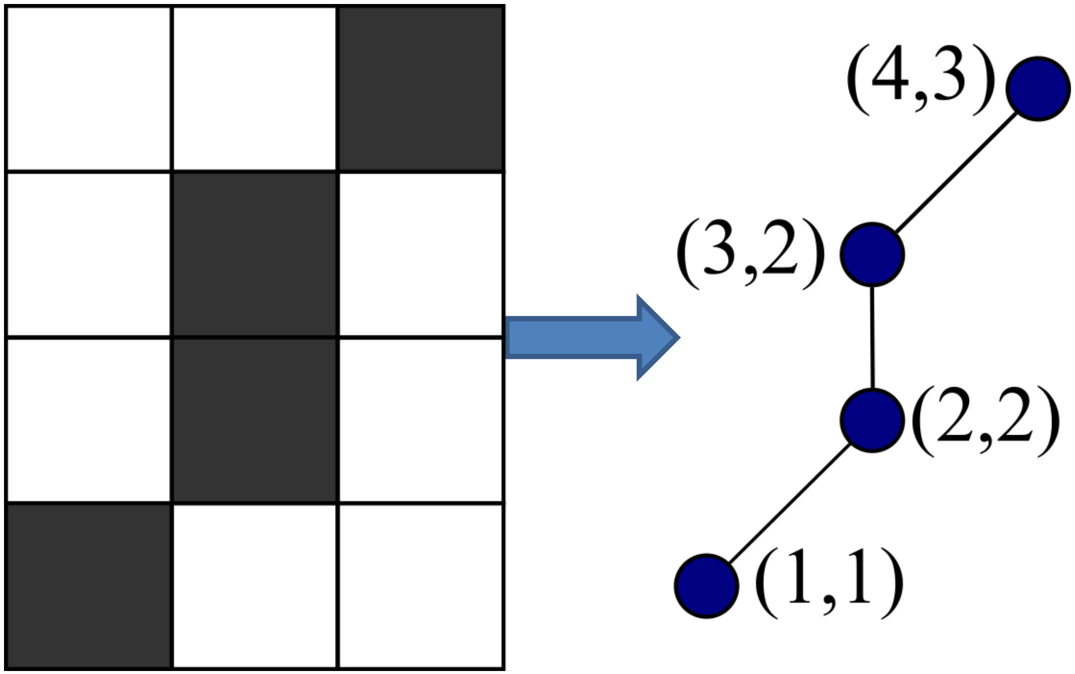
2. Graph construction

- Nodes = mask pixels
- Edges connect neighboring nodes (maximum 8 nodes)

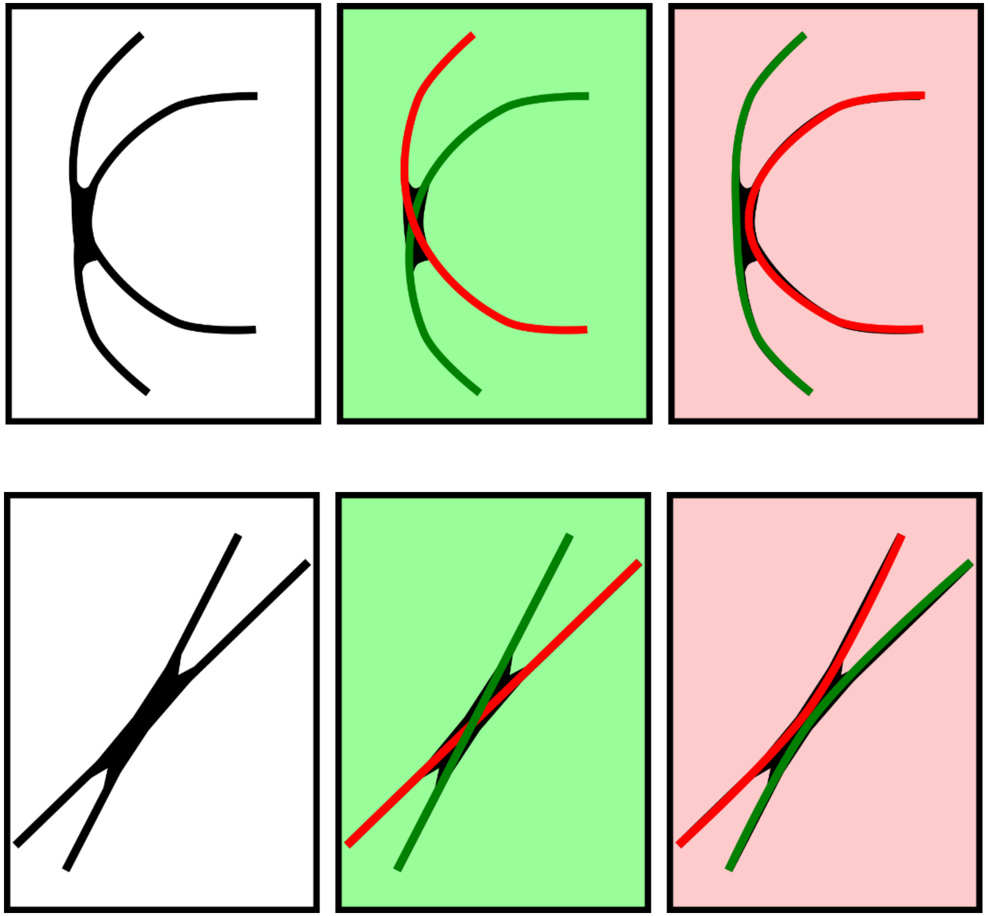


3. Separate microtubule segments

Empirical assumptions:

1. Microtubule curvature is changing slowly

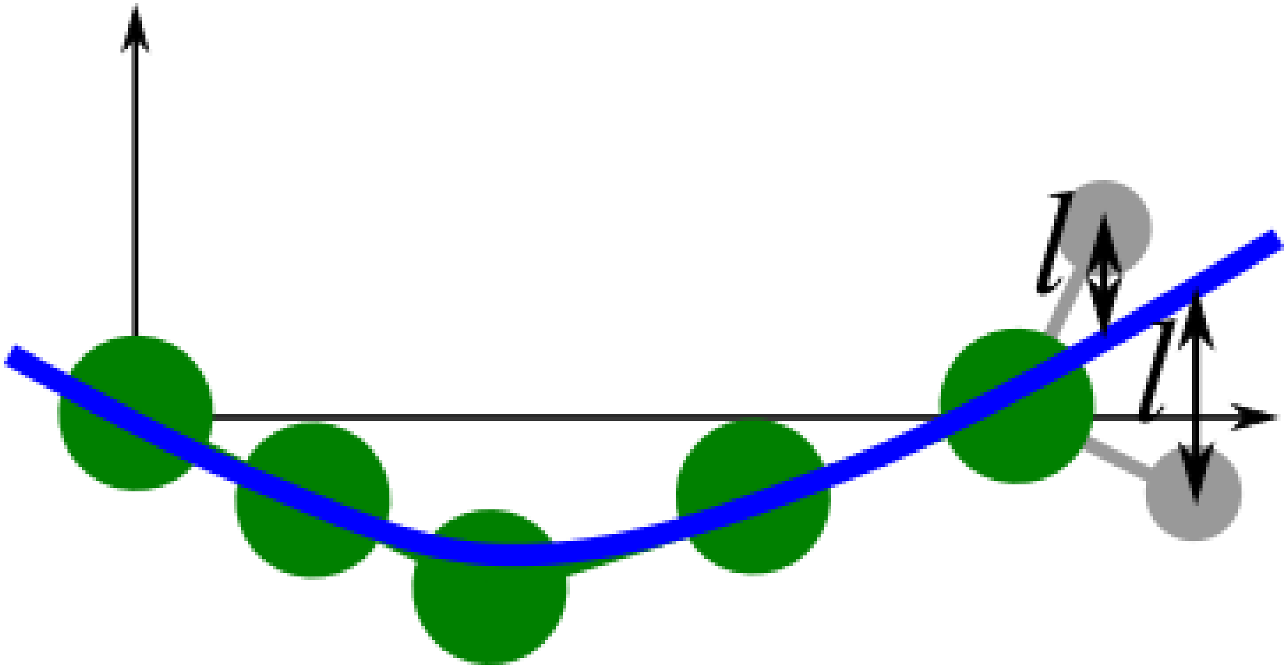
2. Microtubules are more likely to be straight than curved



Main idea: use graph path search algorithms to find minimal cost paths, where edge cost is assigned using empirical assumptions

3. Separate microtubule segments

- $y = ax^3 + bx^2 + cx + d$
- Edge cost $l + w(|a| + |b|)$



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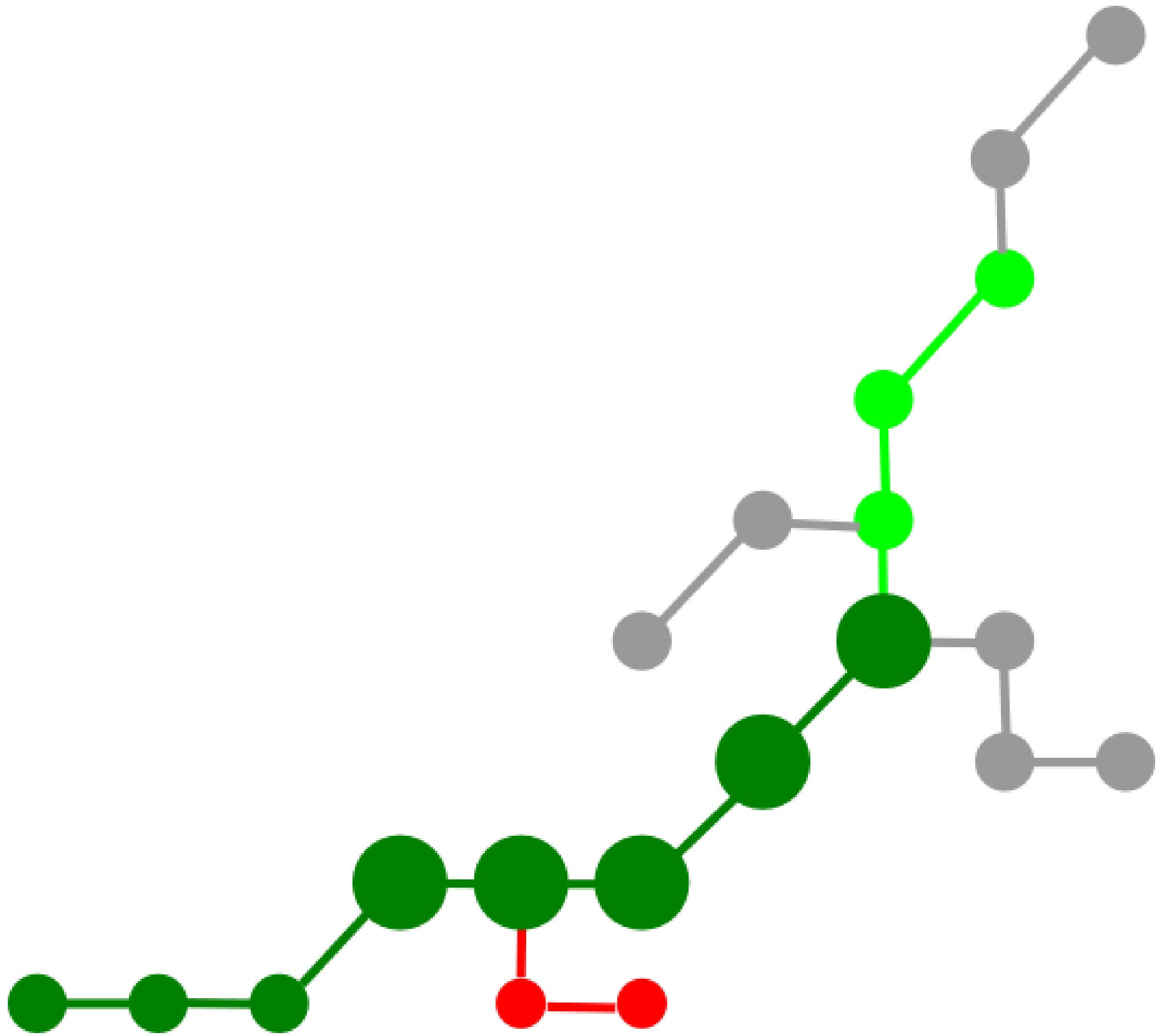

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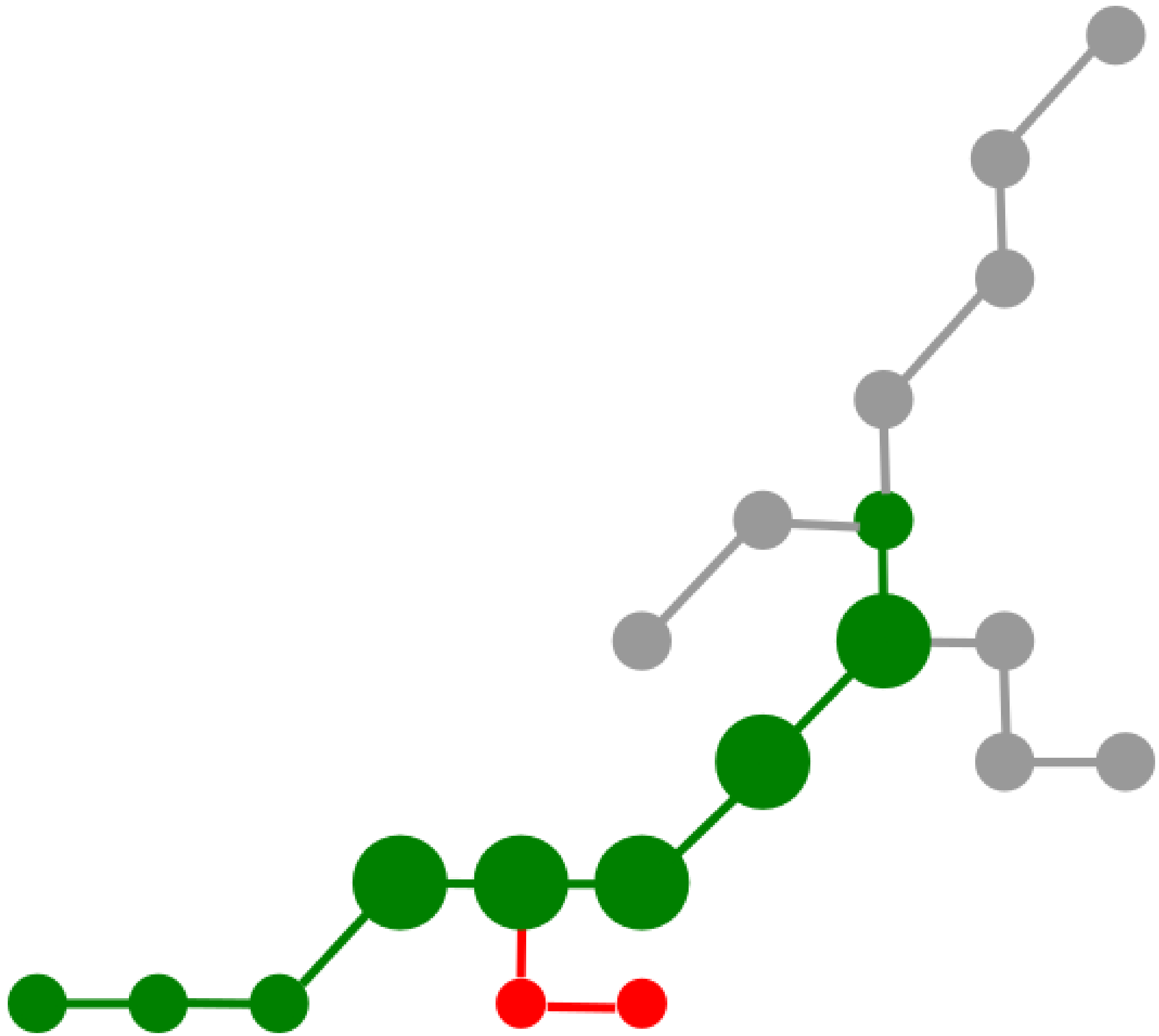

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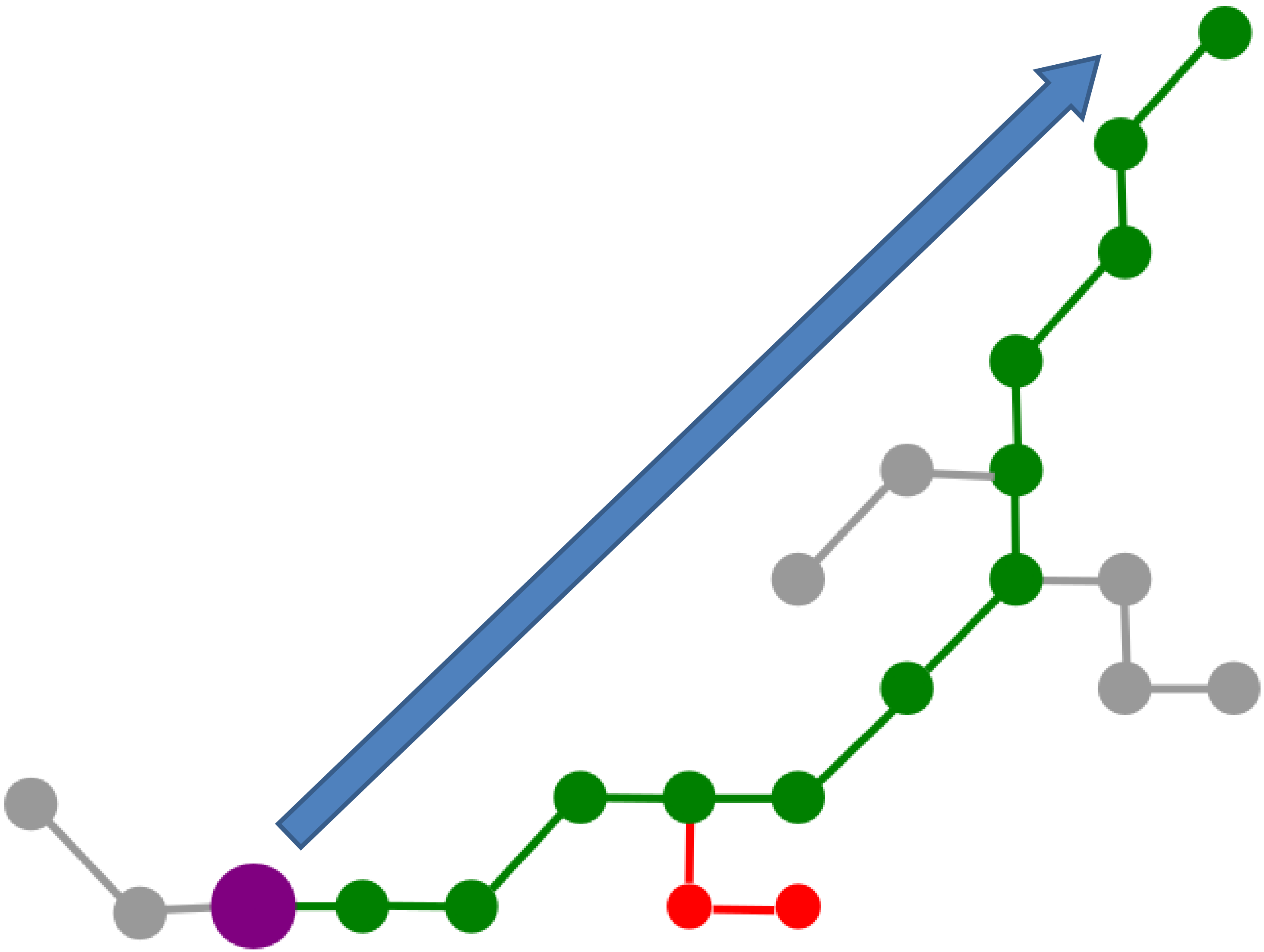

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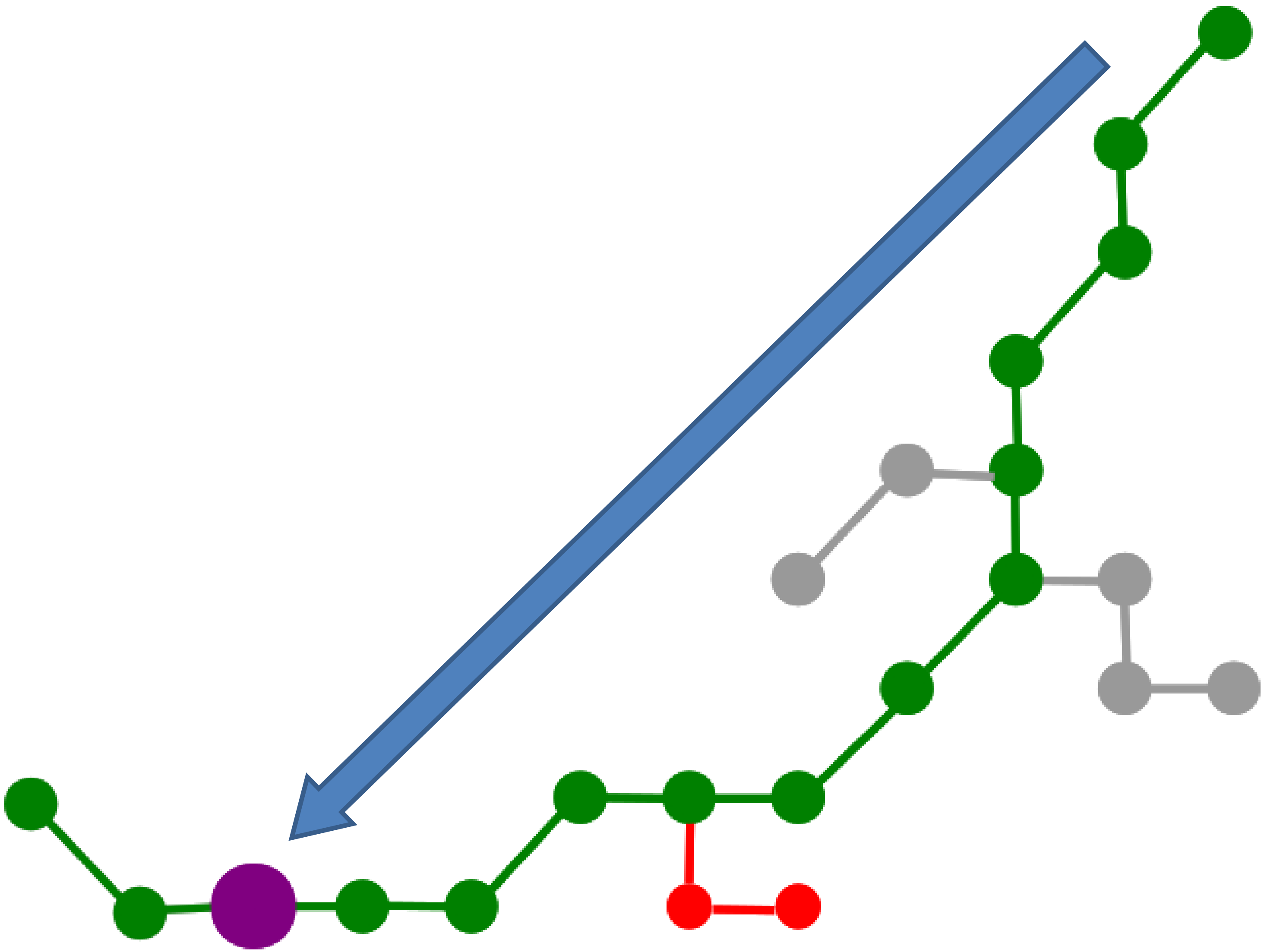

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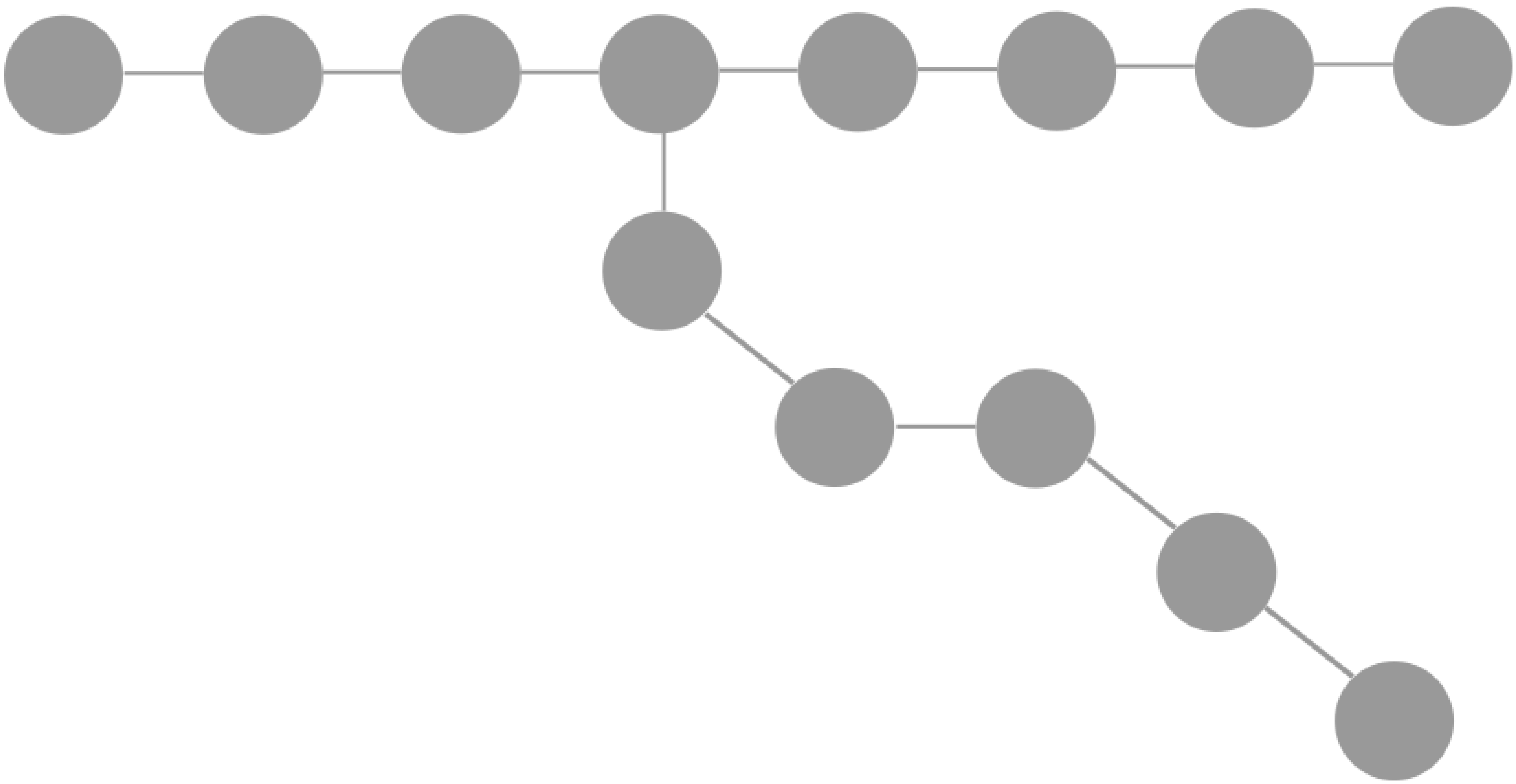

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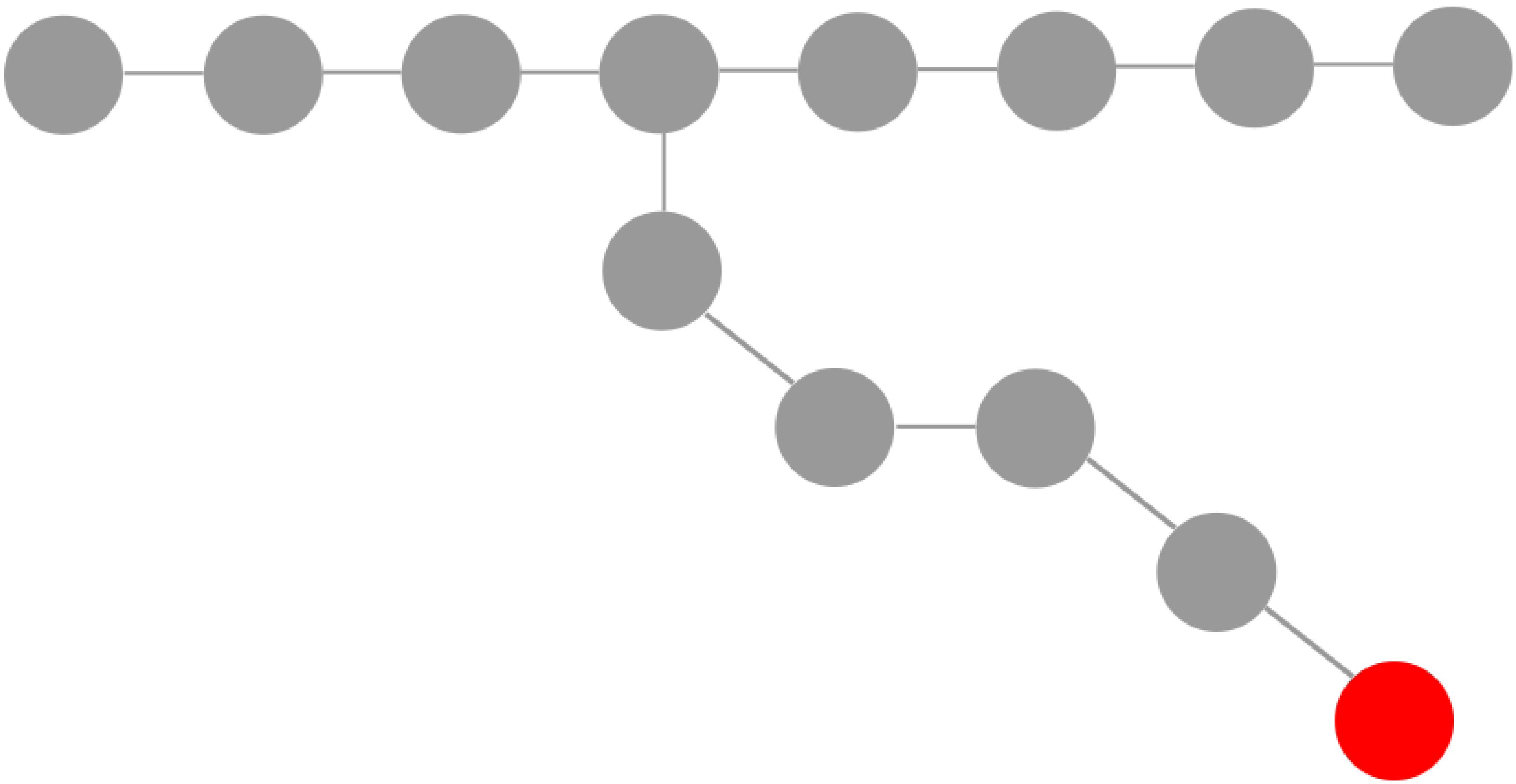

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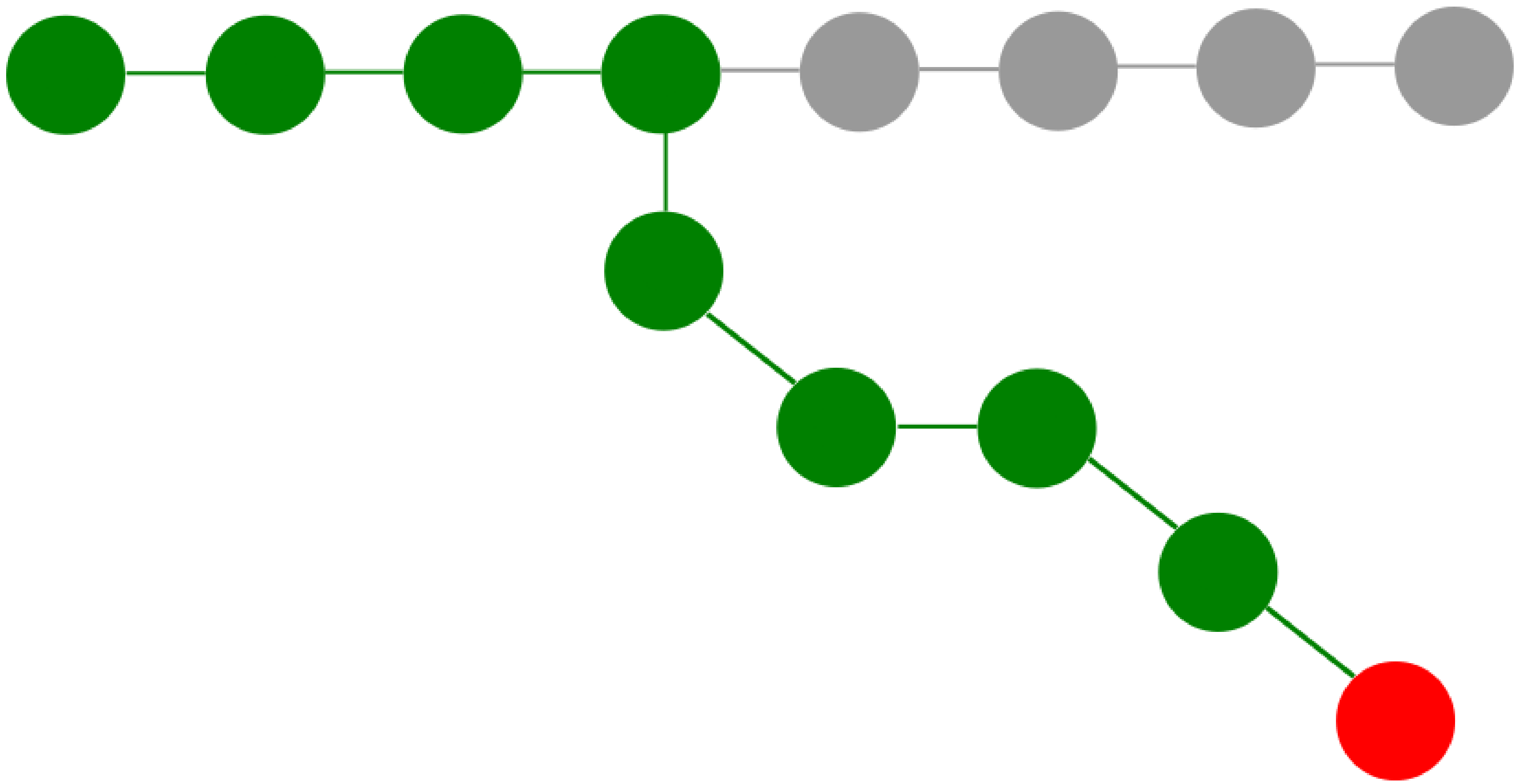

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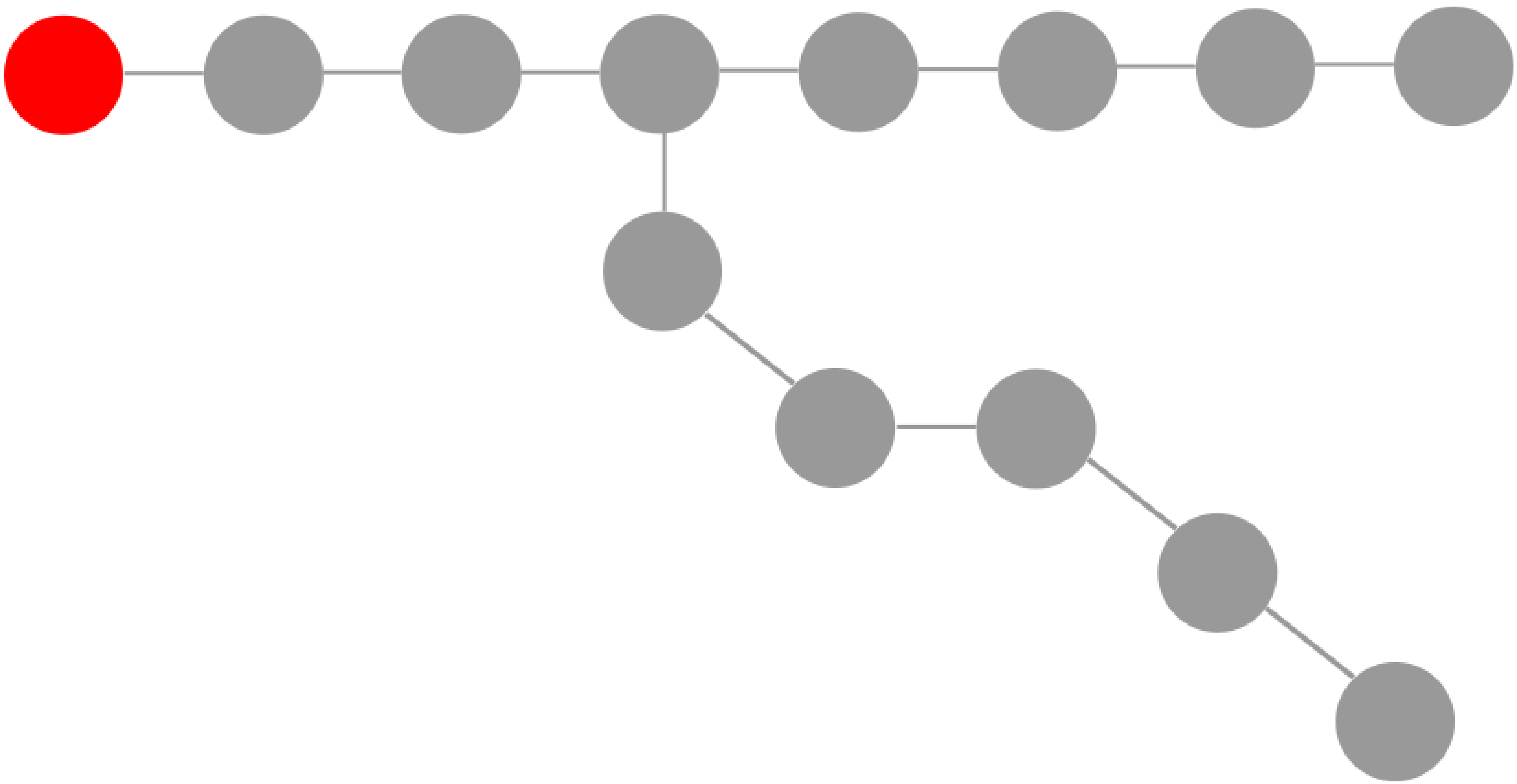

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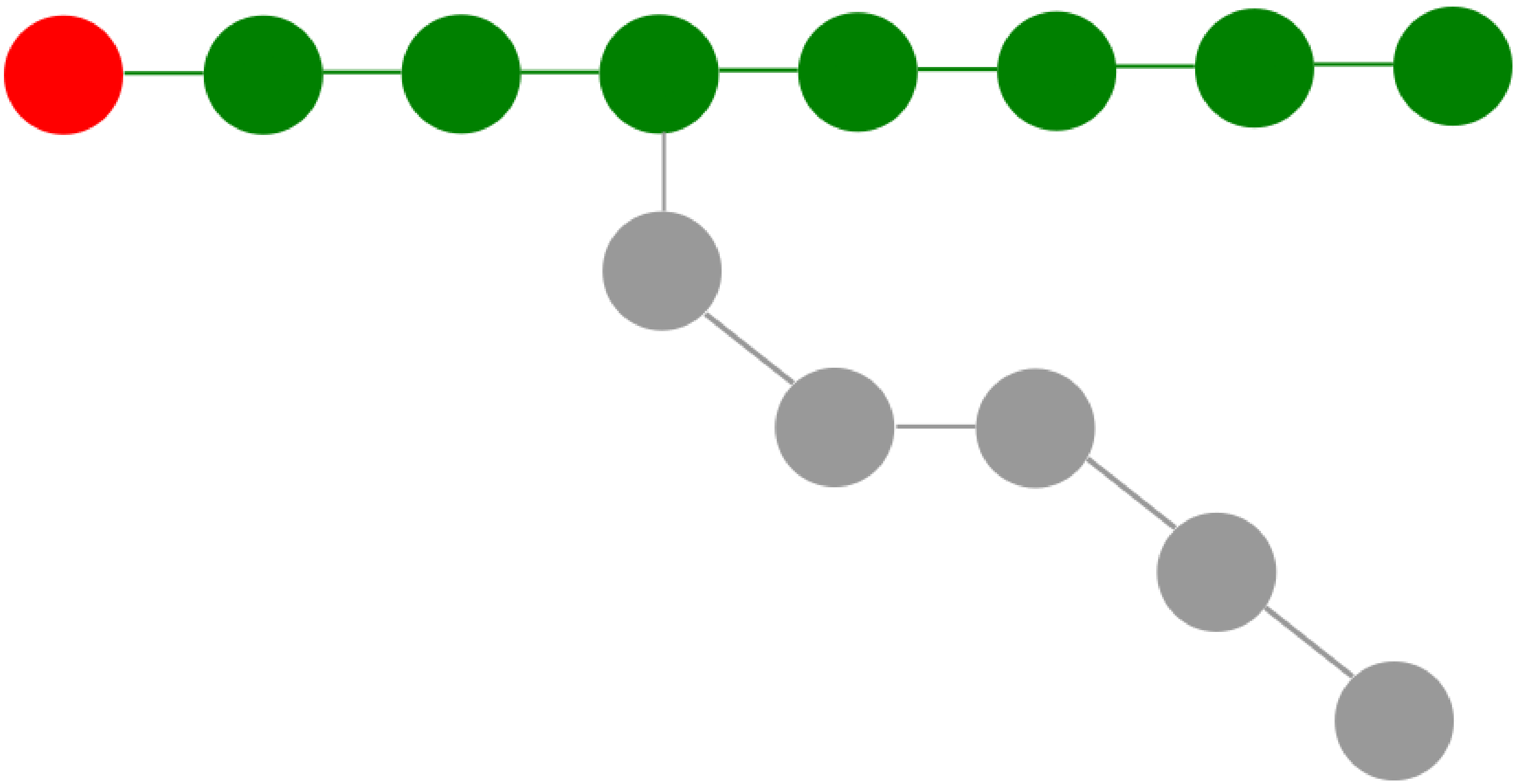

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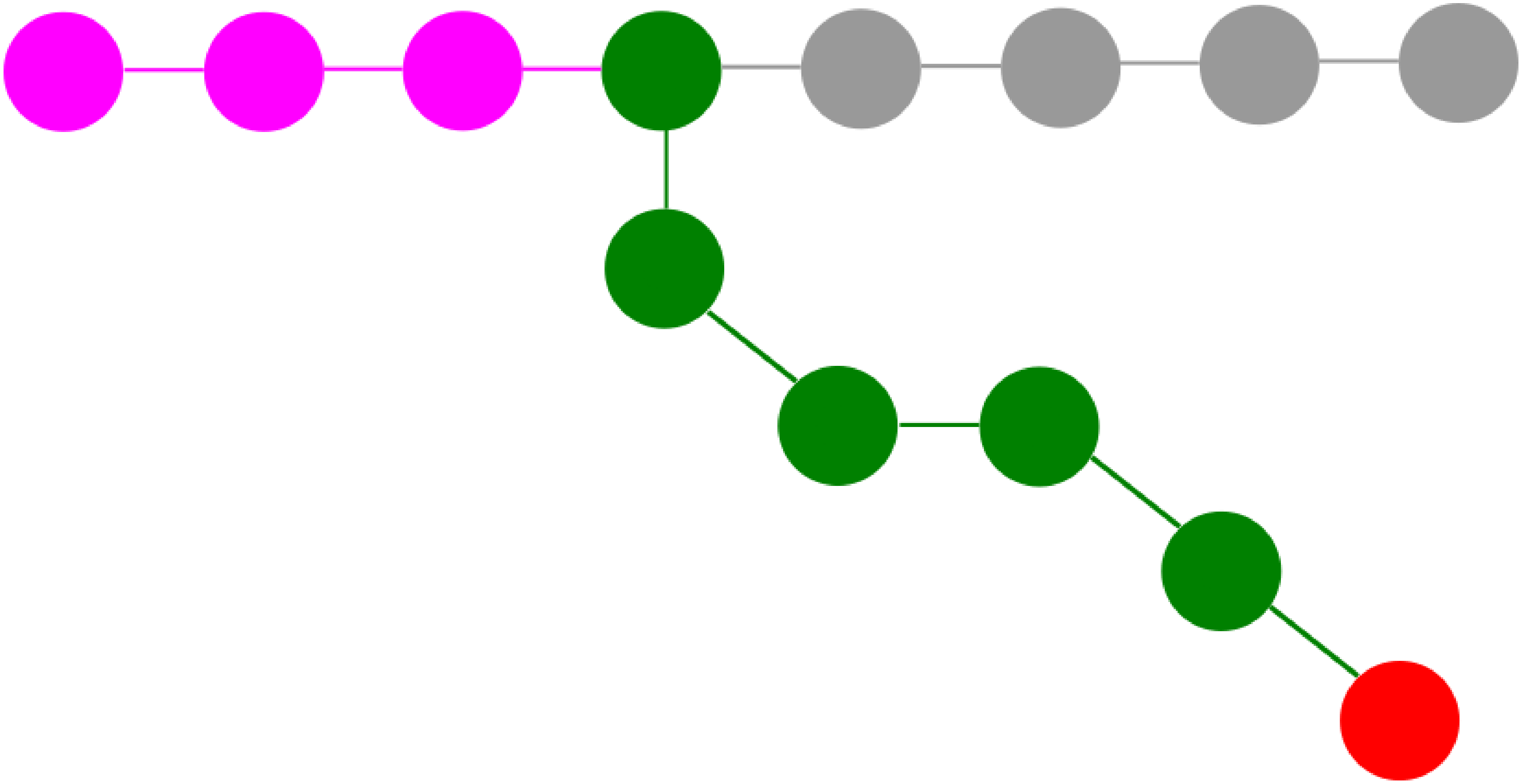

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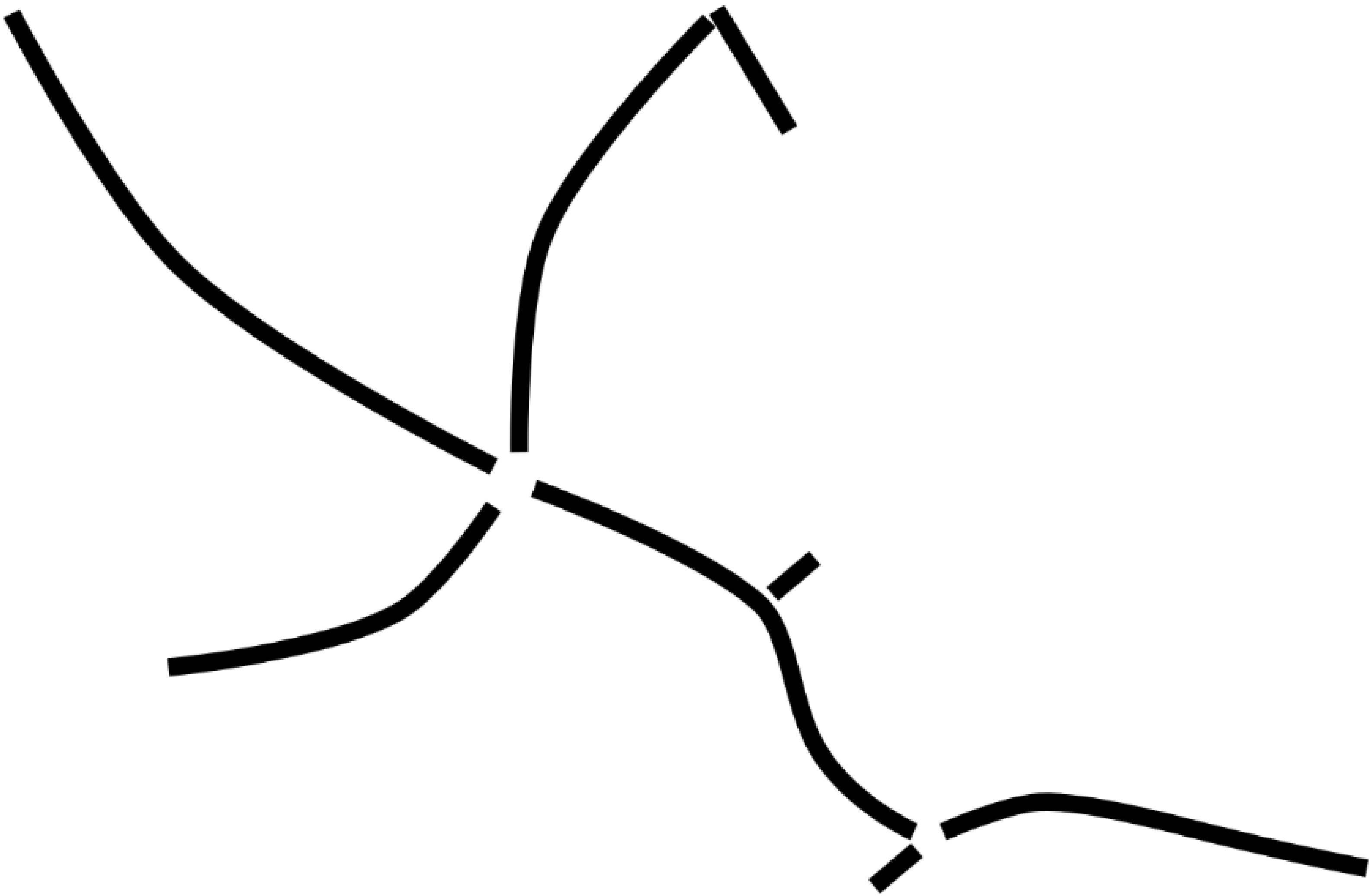

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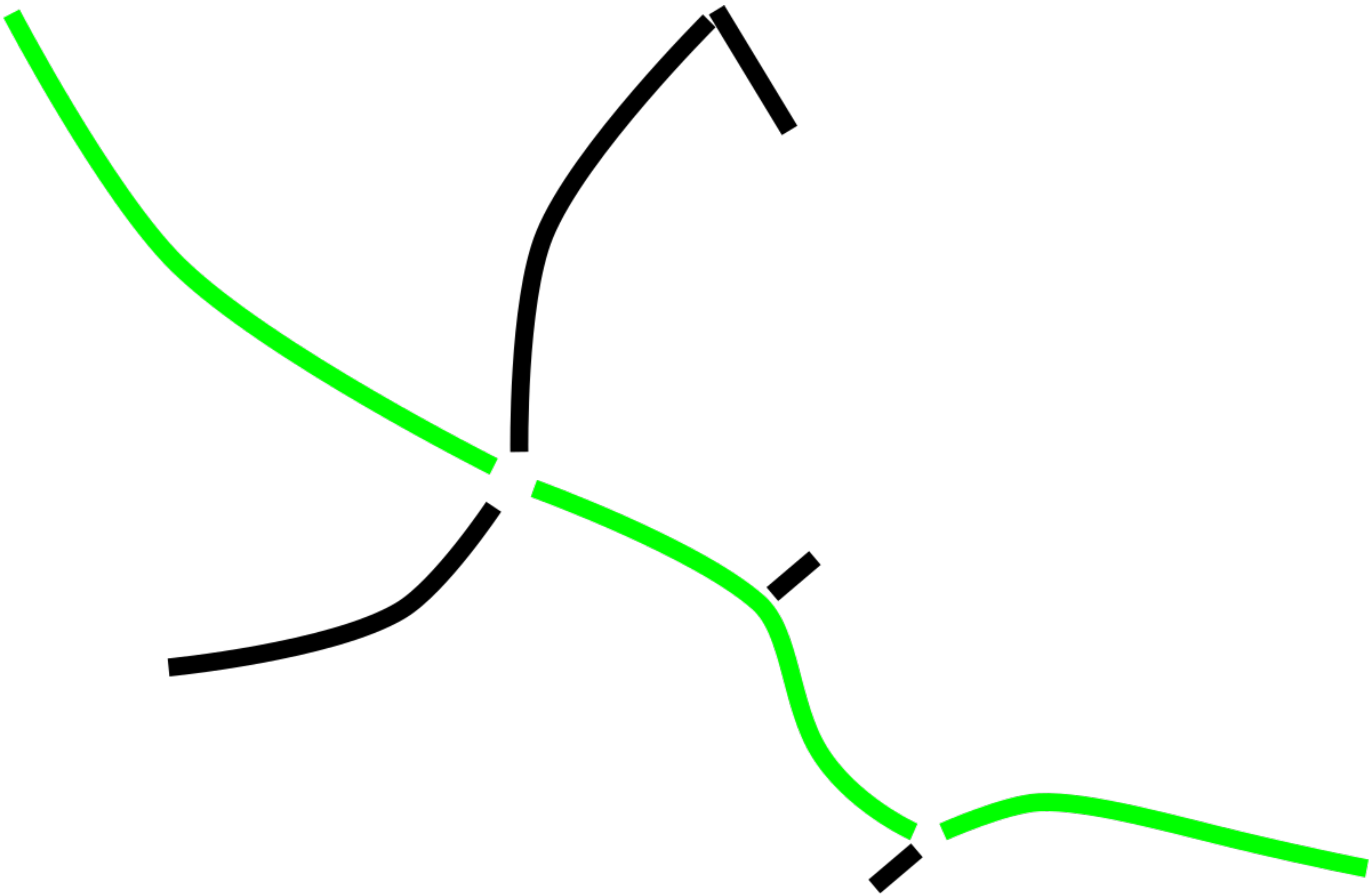

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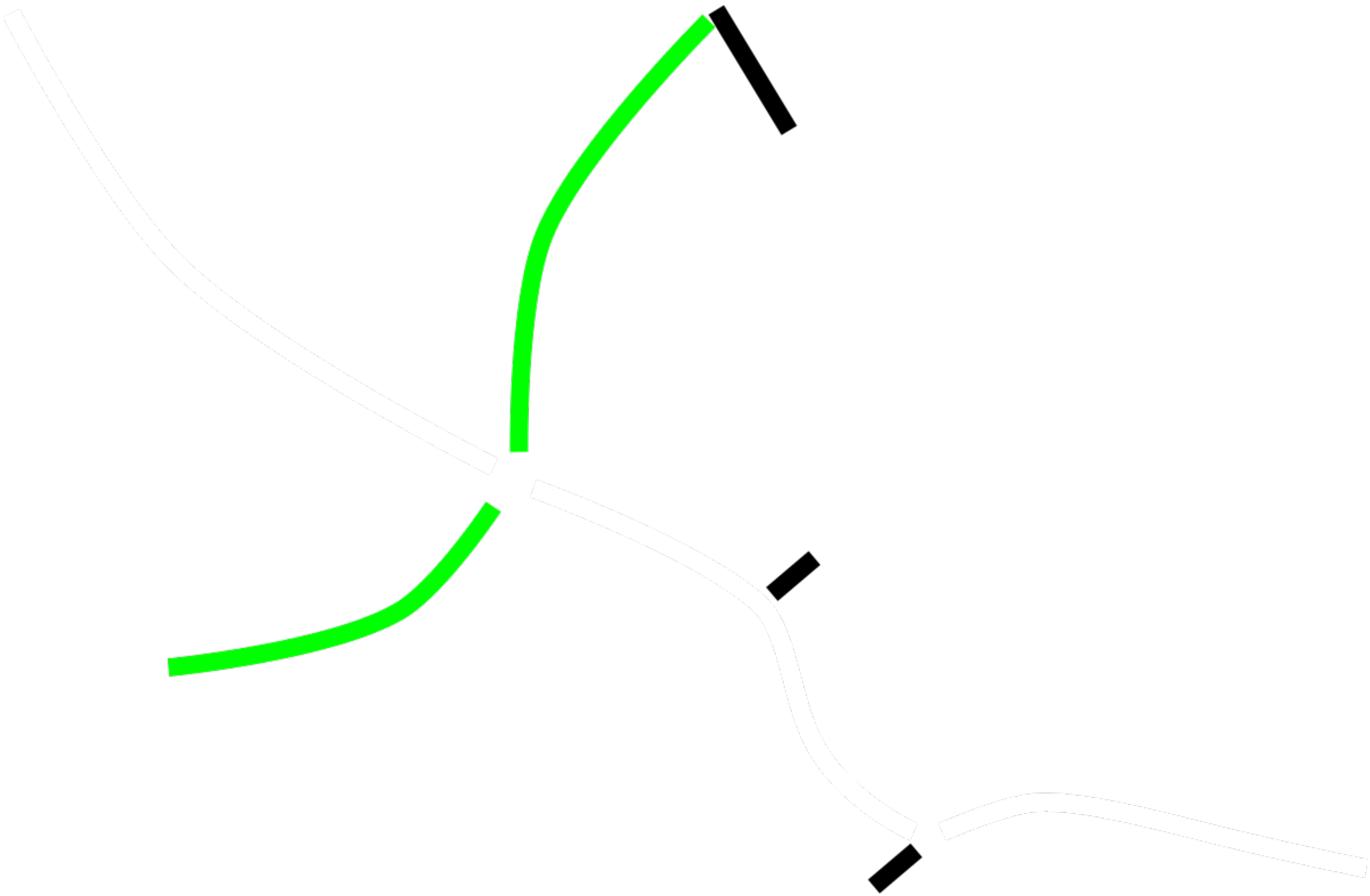
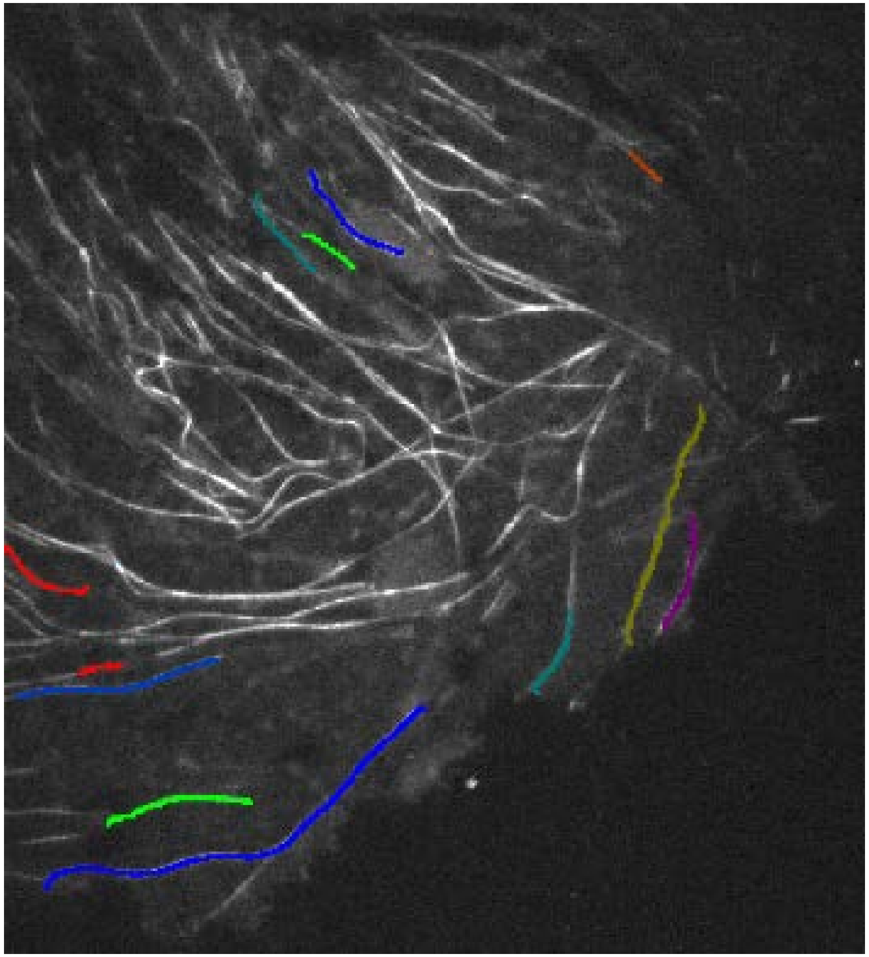
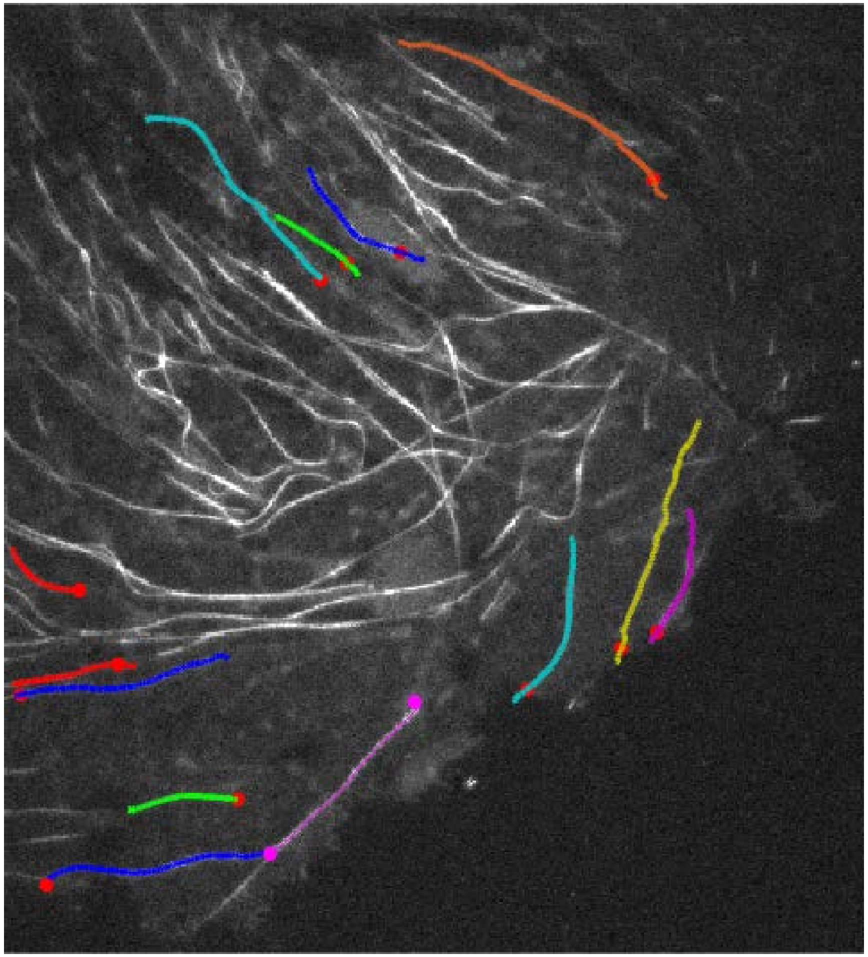


Results

[Hadjidemetriou]



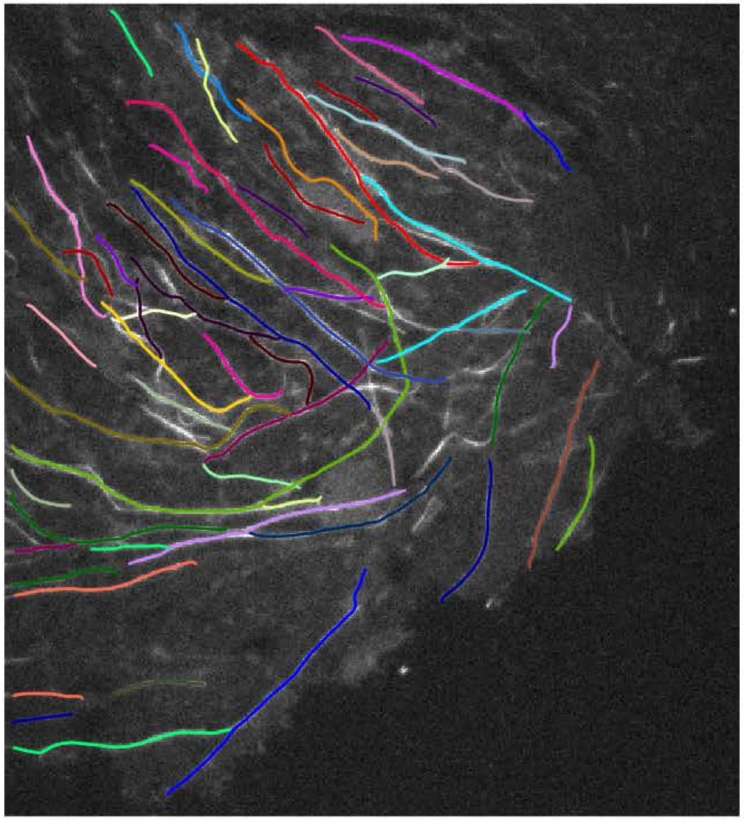
Algorithm results



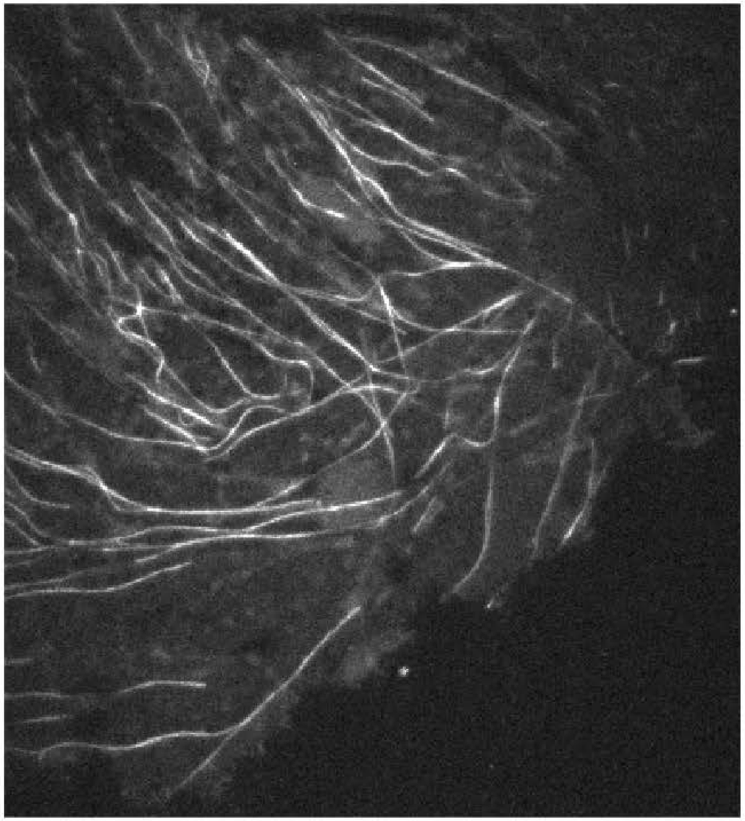
[Hadjidemetriou S. *[et al.]* Segmentation and 3D reconstruction of microtubules in total internal reflection fluorescence microscopy (TIRFM) // Med Image Comput Comput Assist Interv.– V. 8, Pt 1 – 2005. – P. 761-769.]

Results

Algorithm results

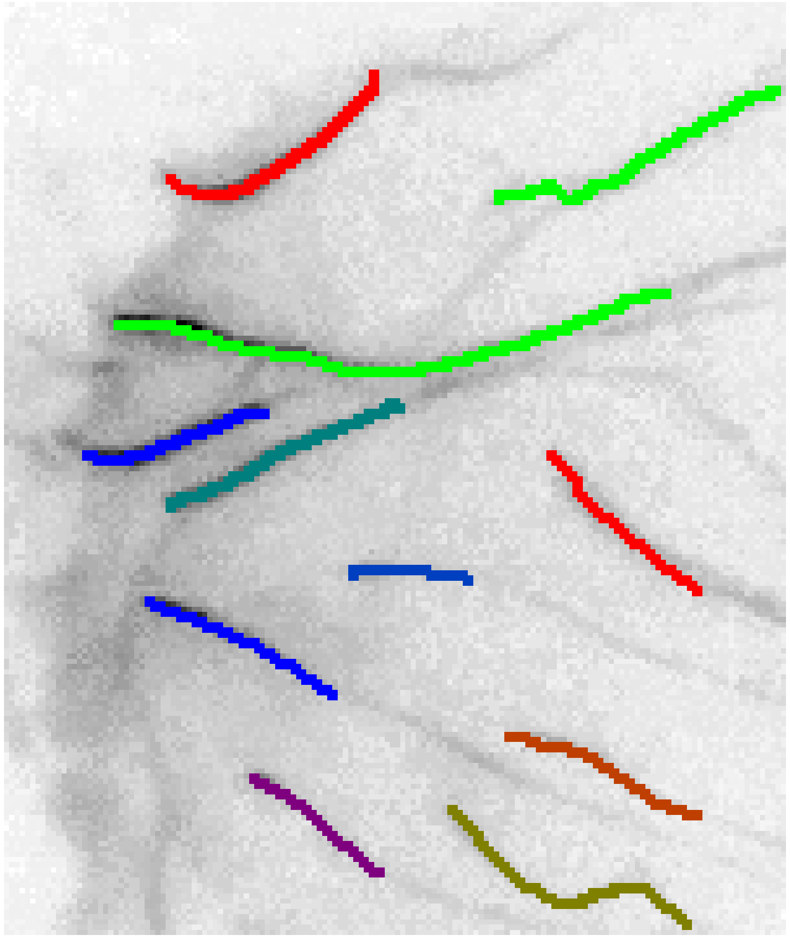


Original image



Results

[Hadjidemetriou]



Algorithm result

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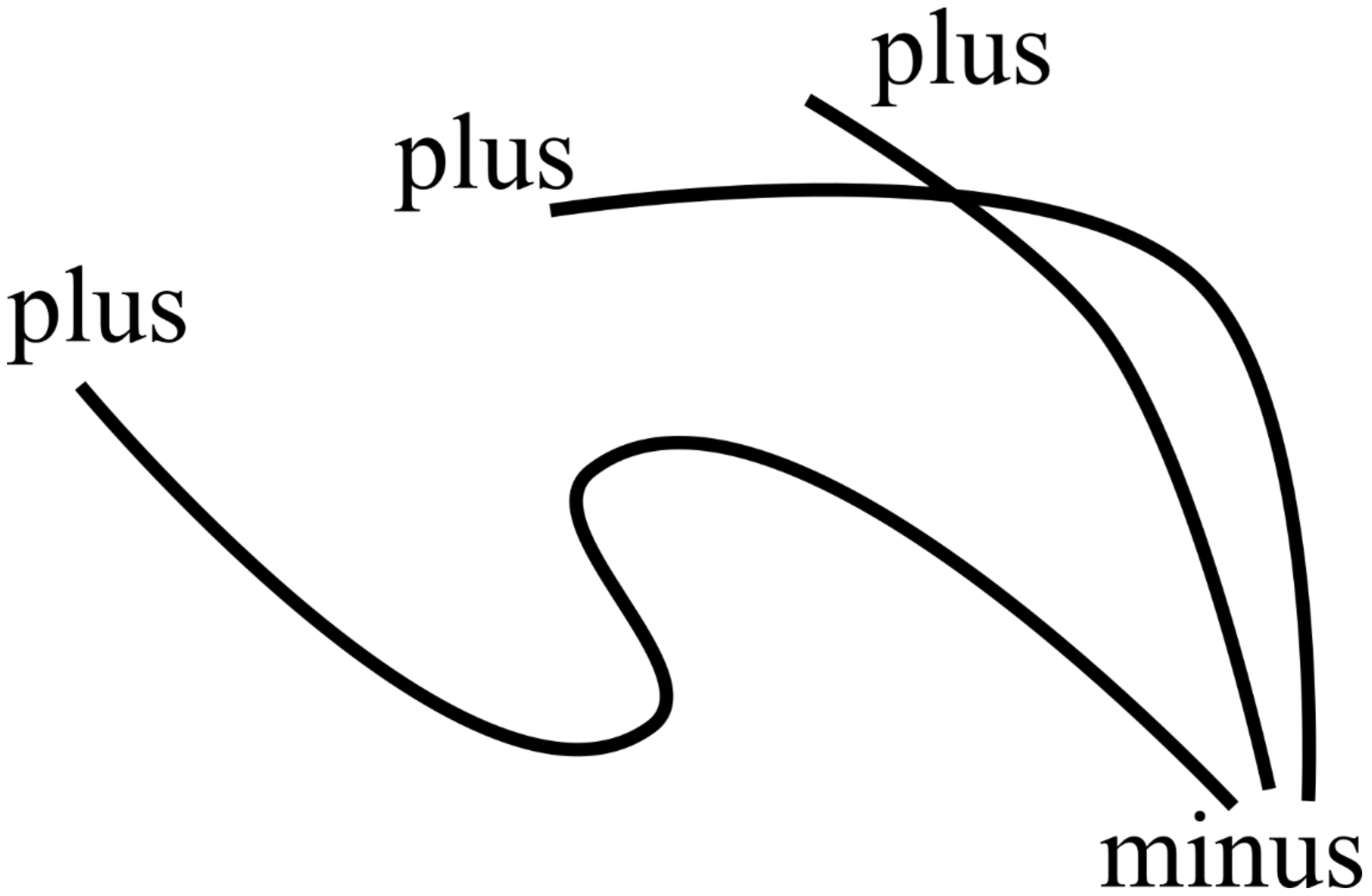
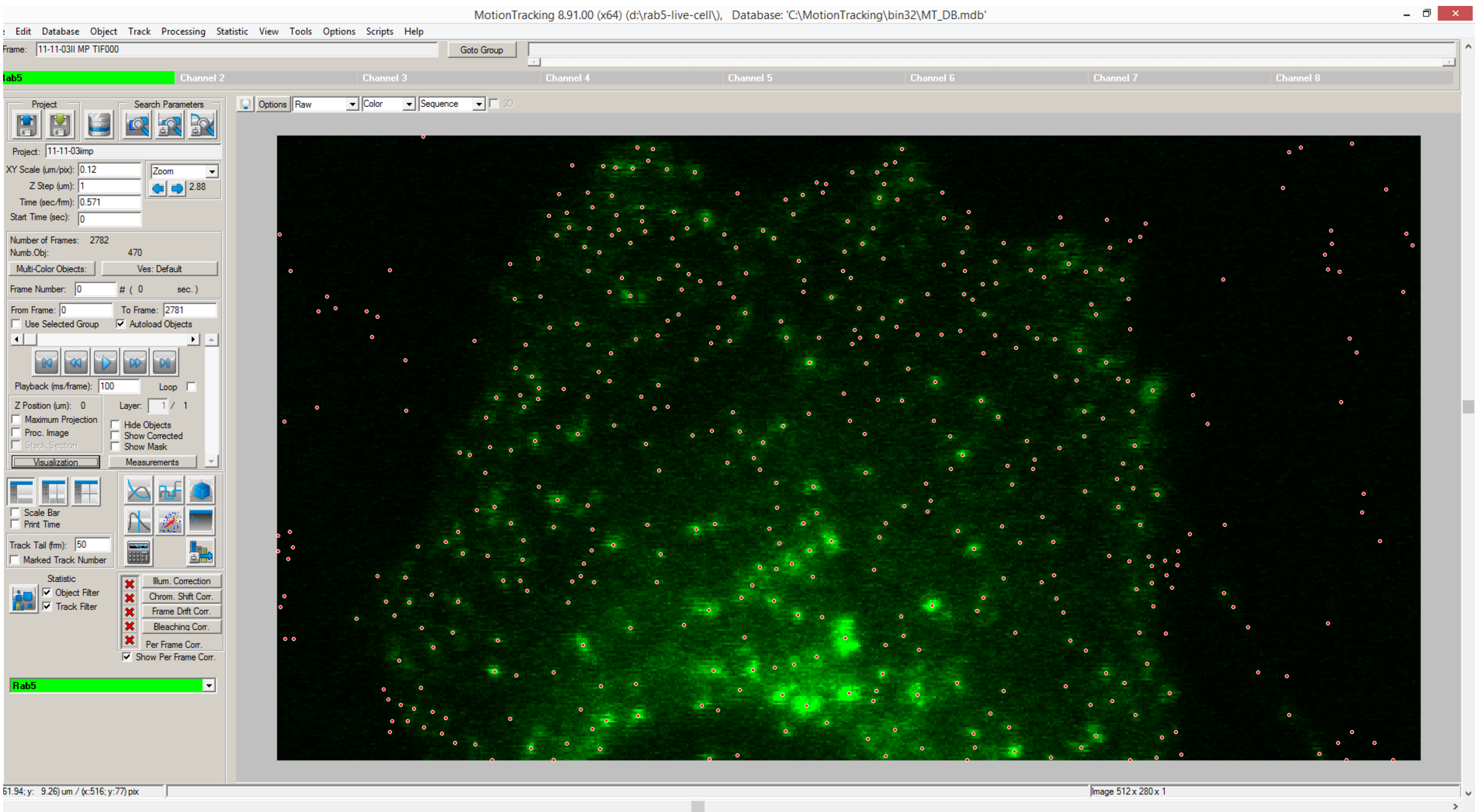
Direction misatribution



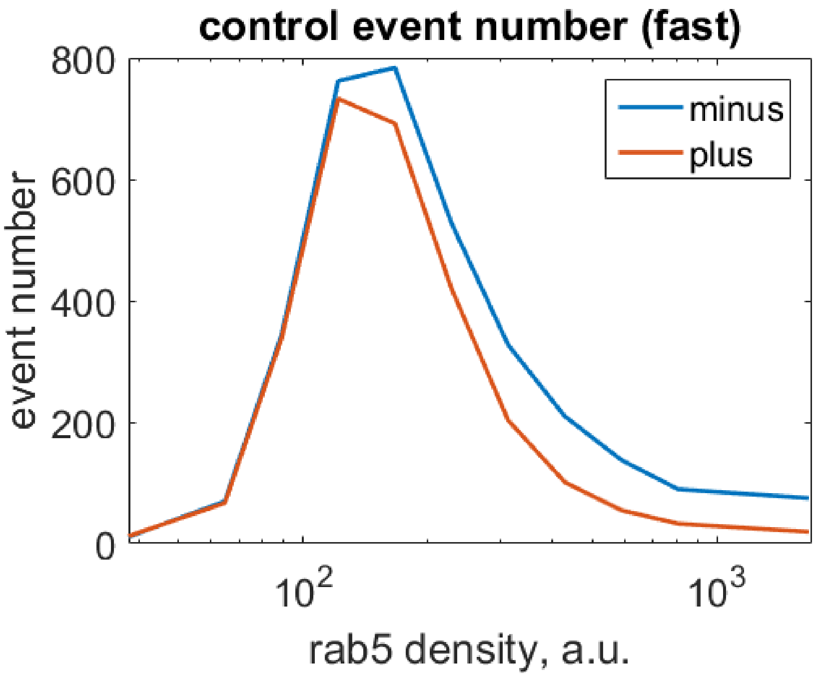
Direction misatribution

MotionTracking [http://motiontracking.mpi-cbg.de]

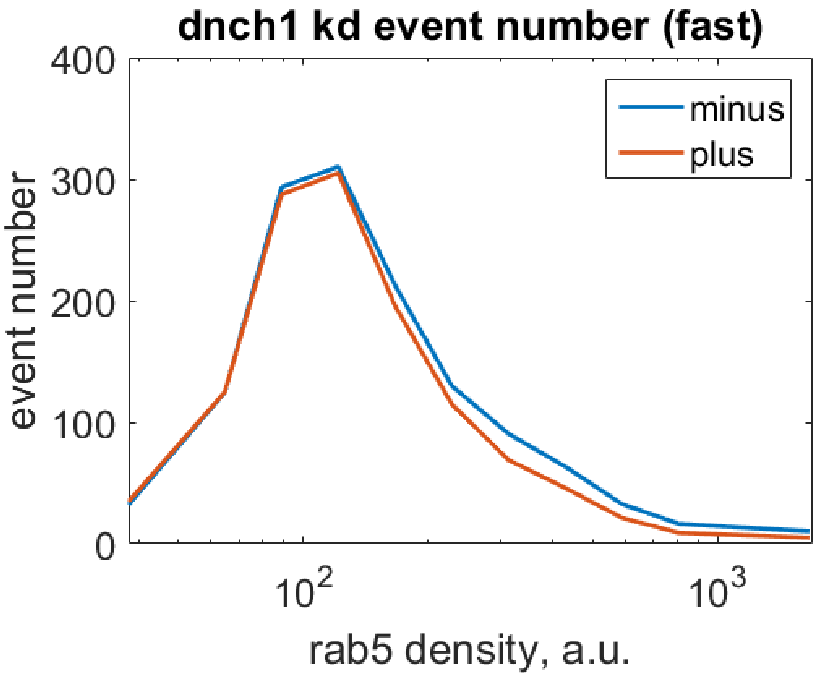


Plus and minus-end dynein movements

Control



dnch1 knockdown



Misatribution model

$$m_{+}^{control} = (1-\alpha)n_{+}^{control} + \alpha n_{-}^{control}$$

$$m_{-}^{control} = (1-\alpha)n_{-}^{control} + \alpha n_{+}^{control}$$

$$m_{+}^{knockdown} = (1-\alpha)n_{+}^{knockdown} + \alpha n_{-}^{knockdown}$$

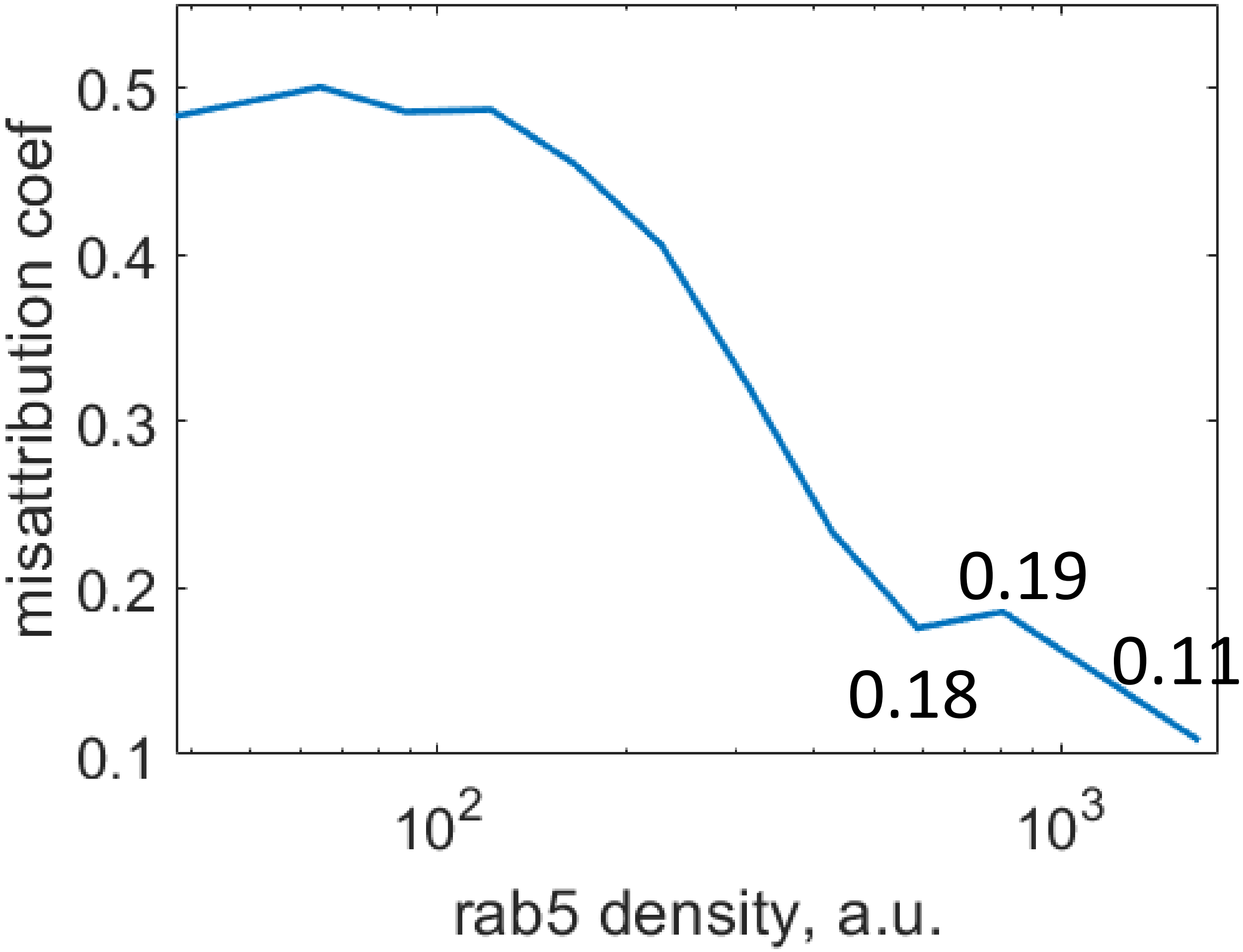
$$m_{-}^{knockdown} = (1-\alpha)n_{-}^{knockdown} + \alpha n_{+}^{knockdown}$$

$$\frac{n_{+}^{control}}{n_{+}^{control} + n_{-}^{control}} = \frac{n_{+}^{knockdown}}{n_{+}^{knockdown} + n_{-}^{knockdown} / \tau}$$

$$\frac{n_{-}^{control}}{n_{+}^{control} + n_{-}^{control}} = \frac{n_{-}^{knockdown} / \tau}{n_{+}^{knockdown} + n_{-}^{knockdown} / \tau}$$

- $m_{+/-}$ – apparent number of plus/minus-end directed movements
- $n_{+/-}$ – true number of plus/minus-end directed movements
- τ – knockdown effectiveness
- α – misatribution coefficient

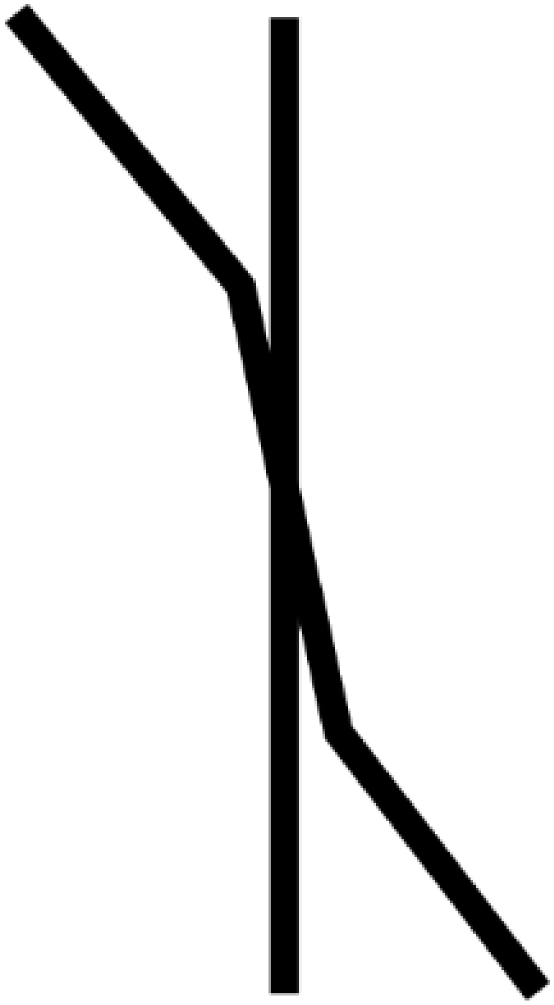
Misatribution model results



Segmentation-based coefficient:

0.12

Sharing common segment



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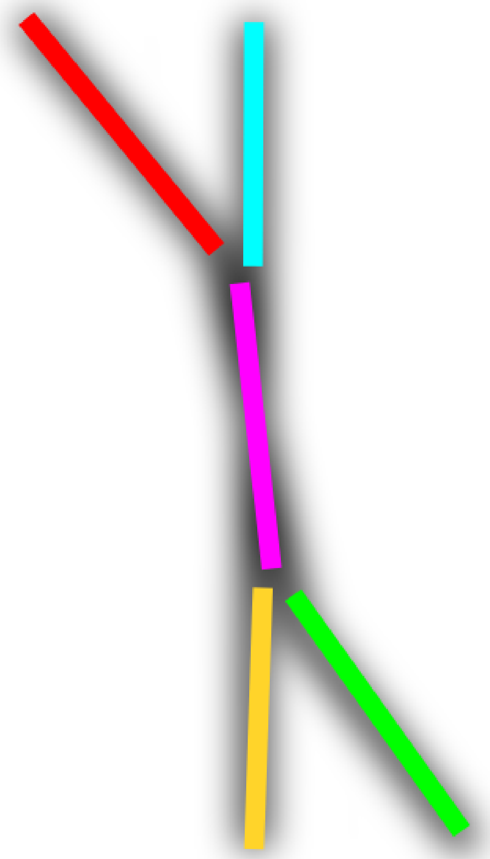

Sharing common segment