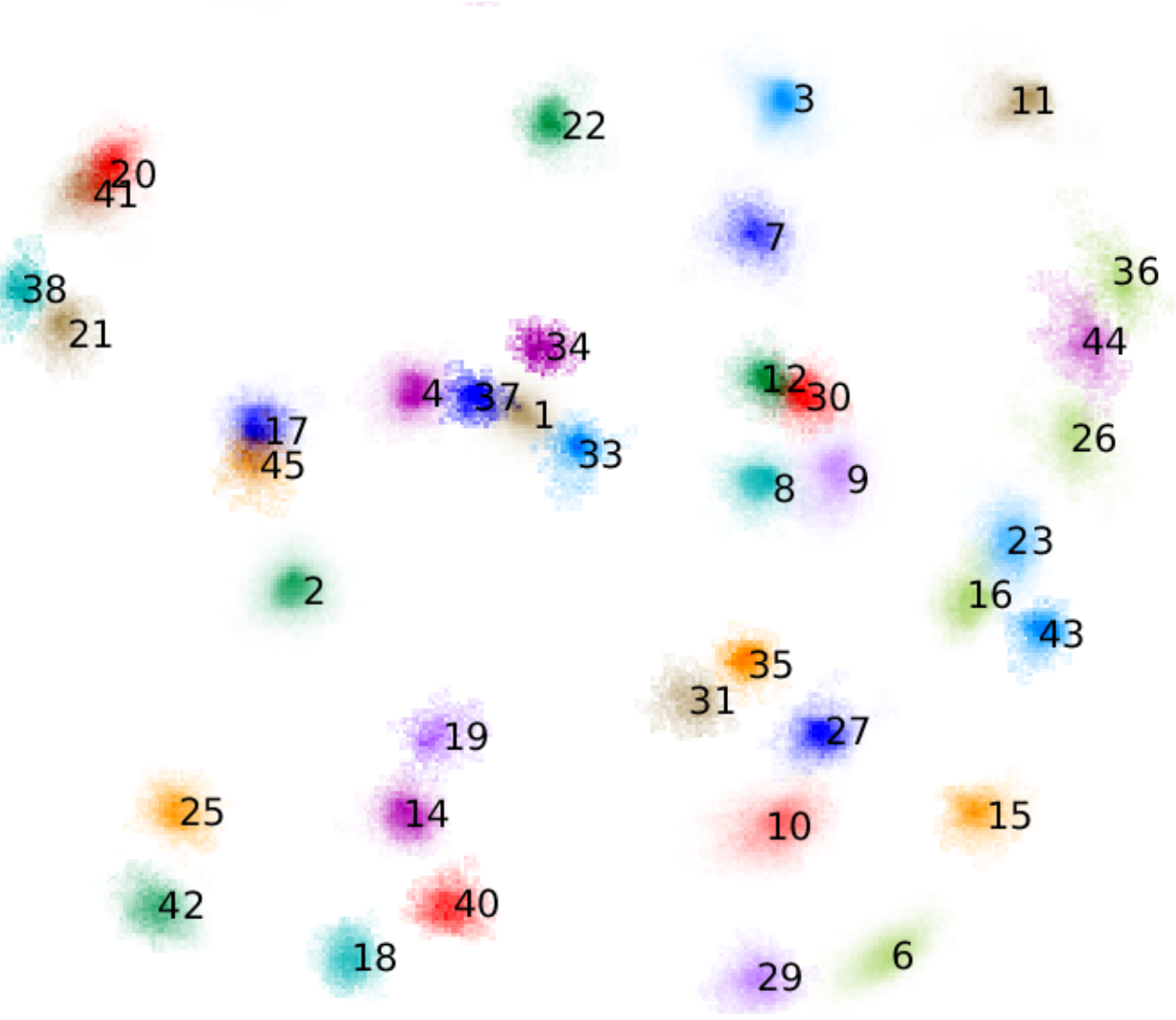
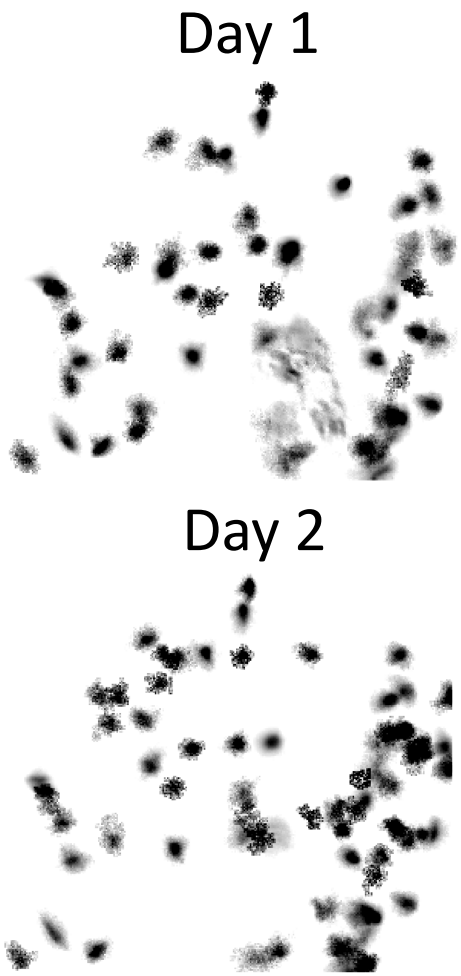


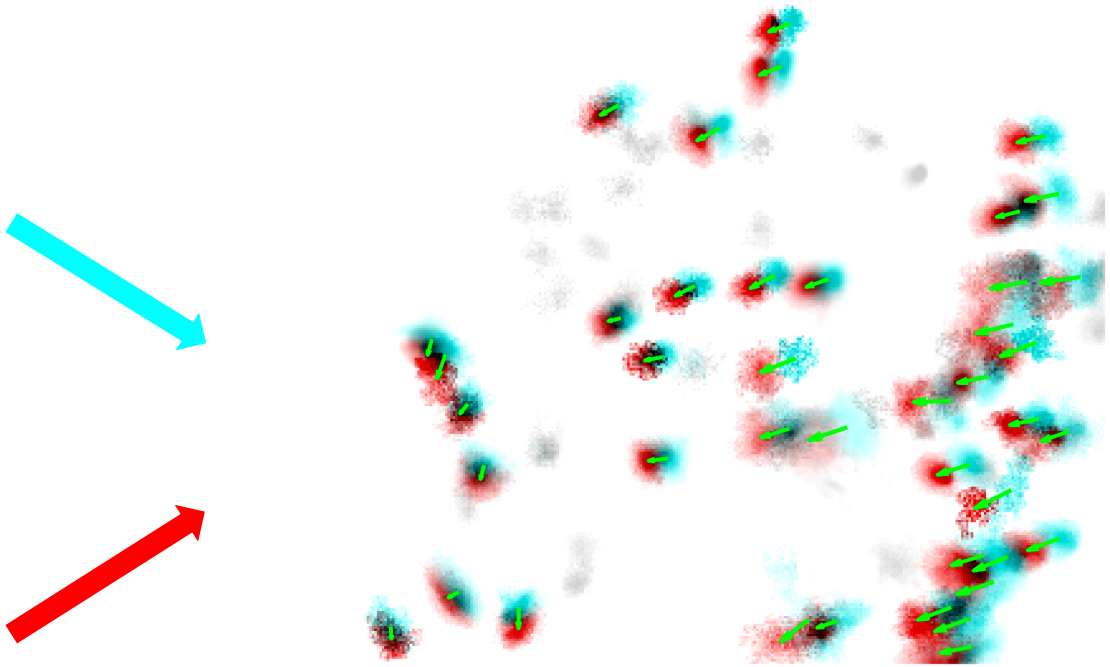
Tracking Neurons across Ca^{2+} Imaging Sessions

——Through optimizing local neighborhood motion consistency

Shijie Gu, Emily Mackevicius,
Michale Fee and Pengcheng Zhou

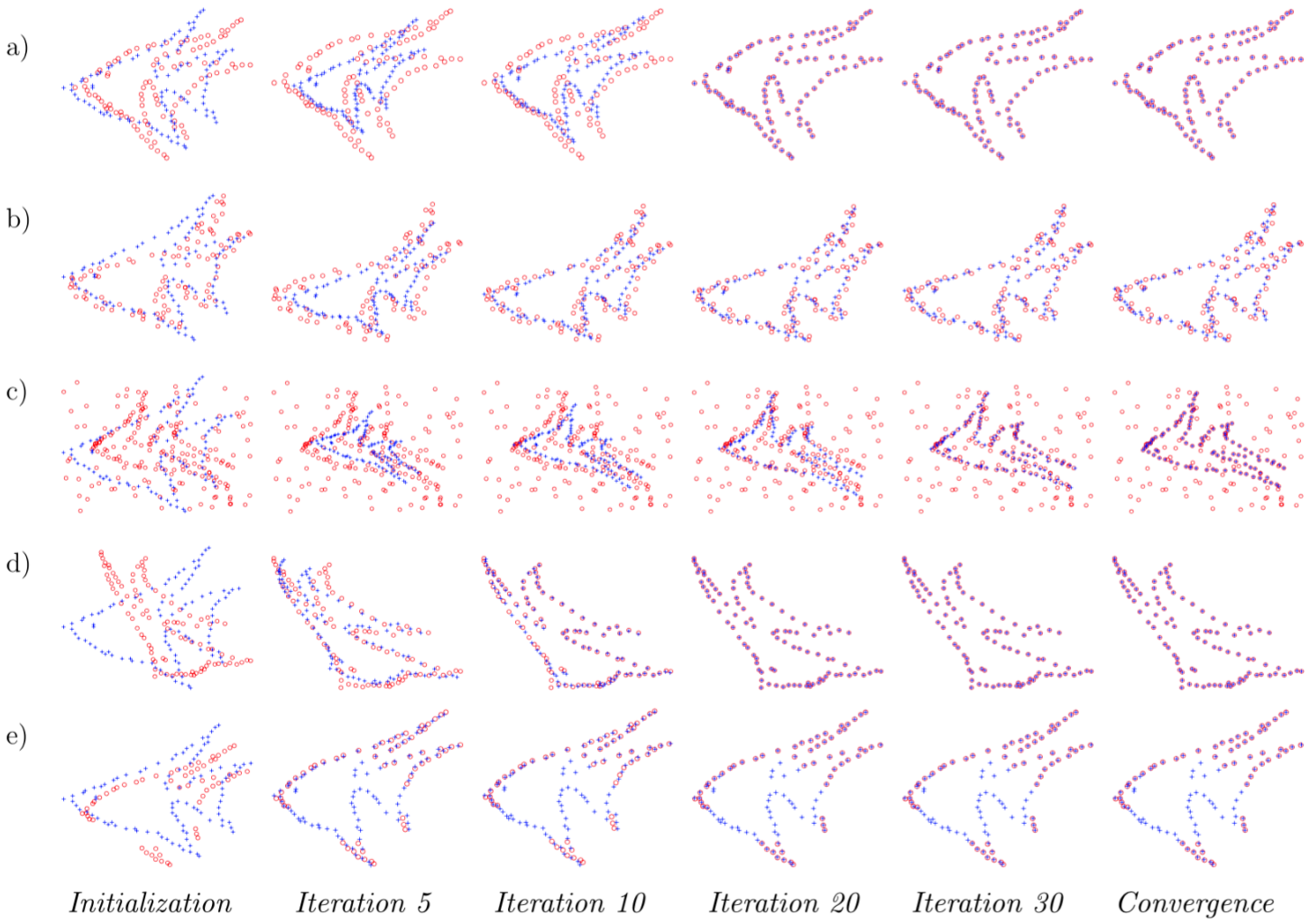
Tracking neurons would have been easy if there is no motion





Two things to do:
(1) Pick out neurons unique to each session
(2) Find matches for those common neurons.

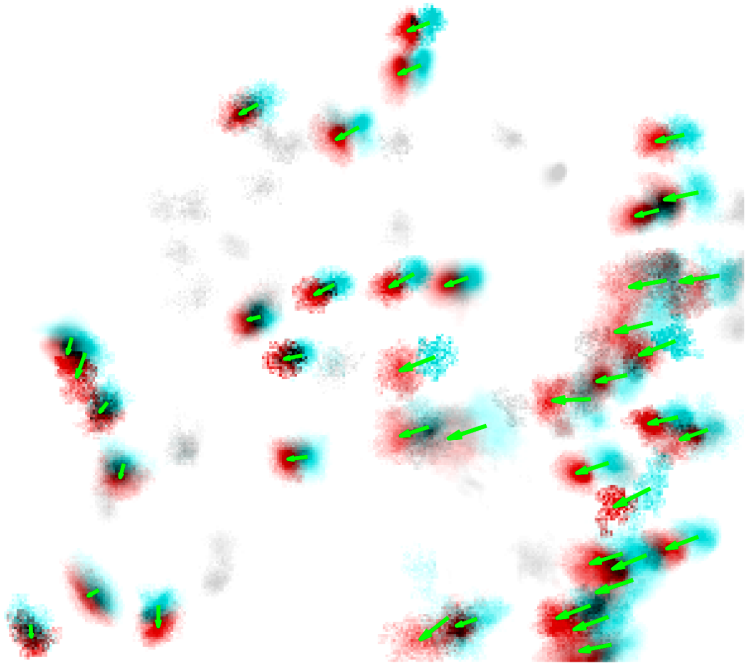
Similar problem in computer science



But we want a very precise point-to-point assignment, a general shape registration is not sufficient

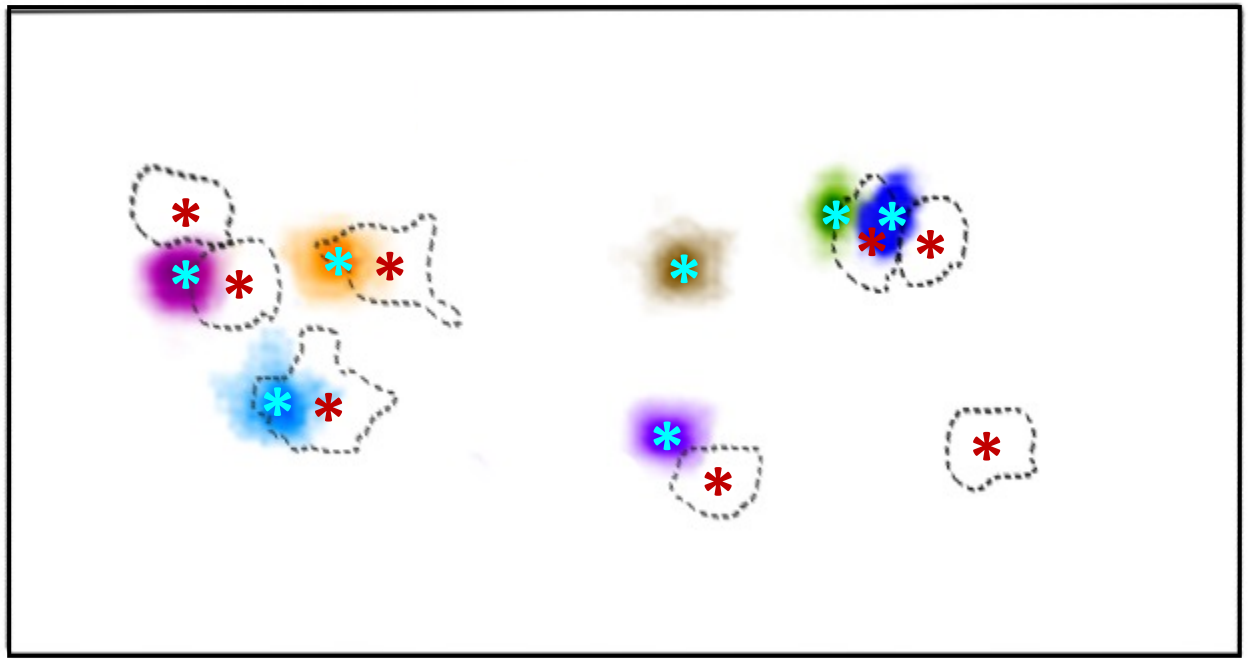
Non-Rigid Point Set Registration by Preserving Global and Local Structures
IEEE TRANSACTIONS ON IMAGE PROCESSING, VOL. 25, NO. 1, JANUARY 2016

How does ‘Stay Together Align Together’ work

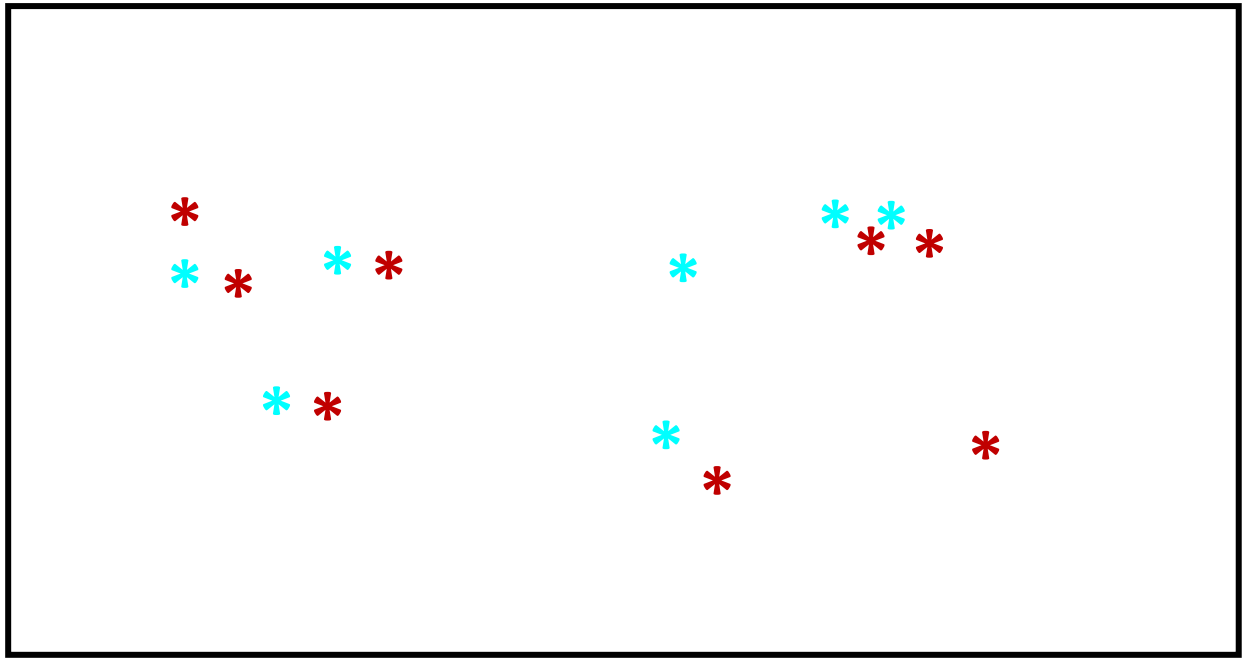


motion vectors are similar in a small neighborhood
(Motion is spatially smooth)

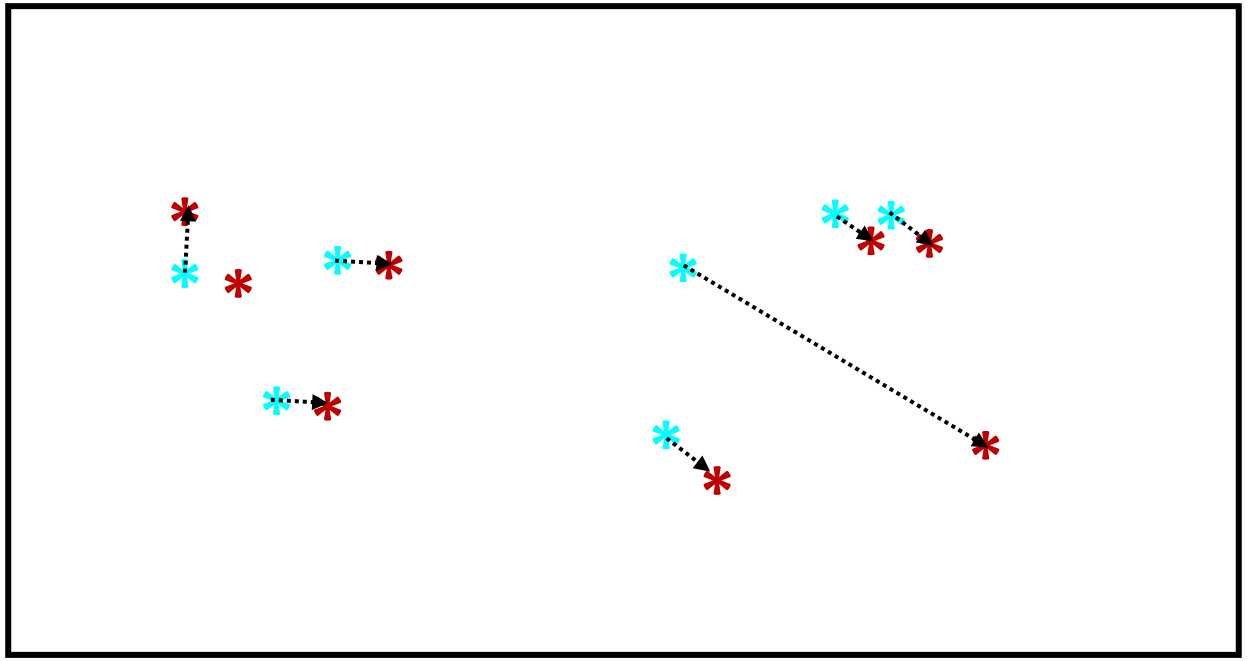
How does ‘Stay Together Align Together’ work

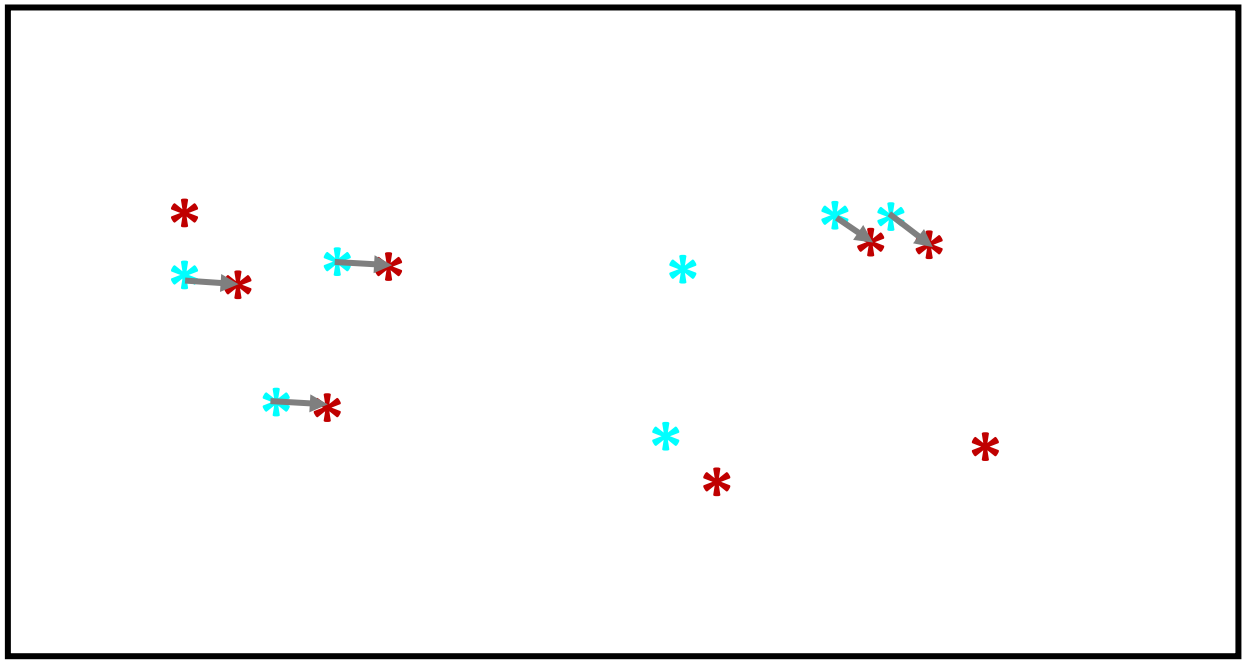


How does ‘Stay Together Align Together’ work



How does ‘Stay Together Align Together’ work





Initialization

Output

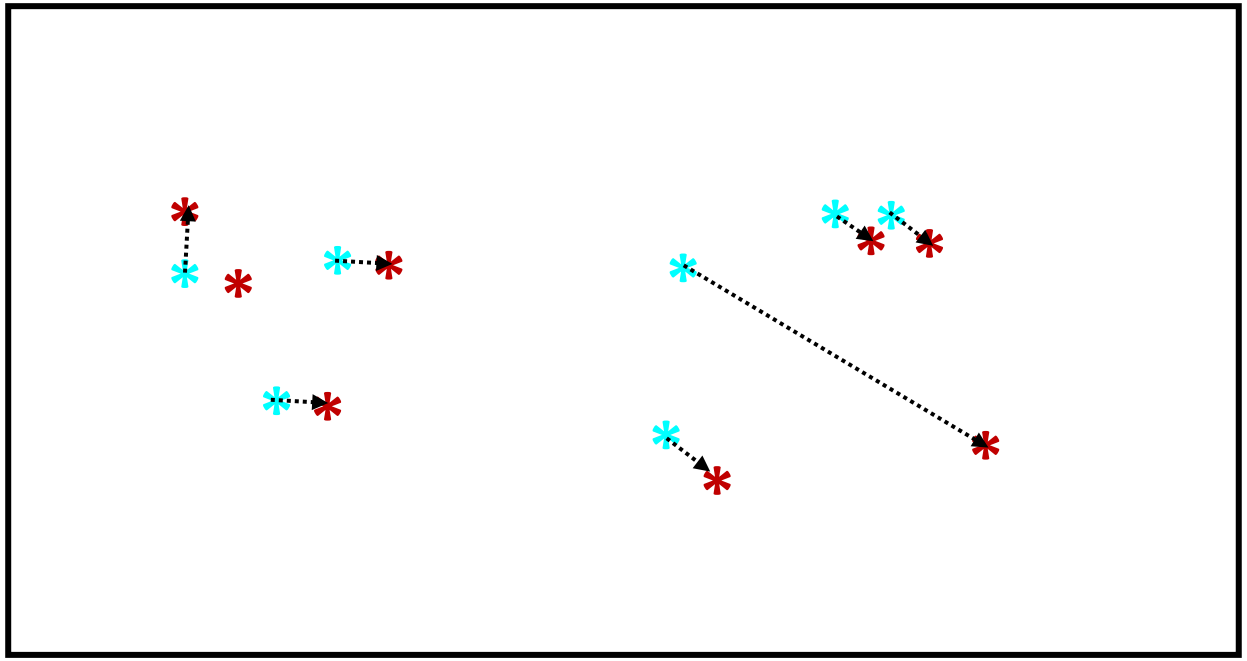
‘Stay Together Align Together’

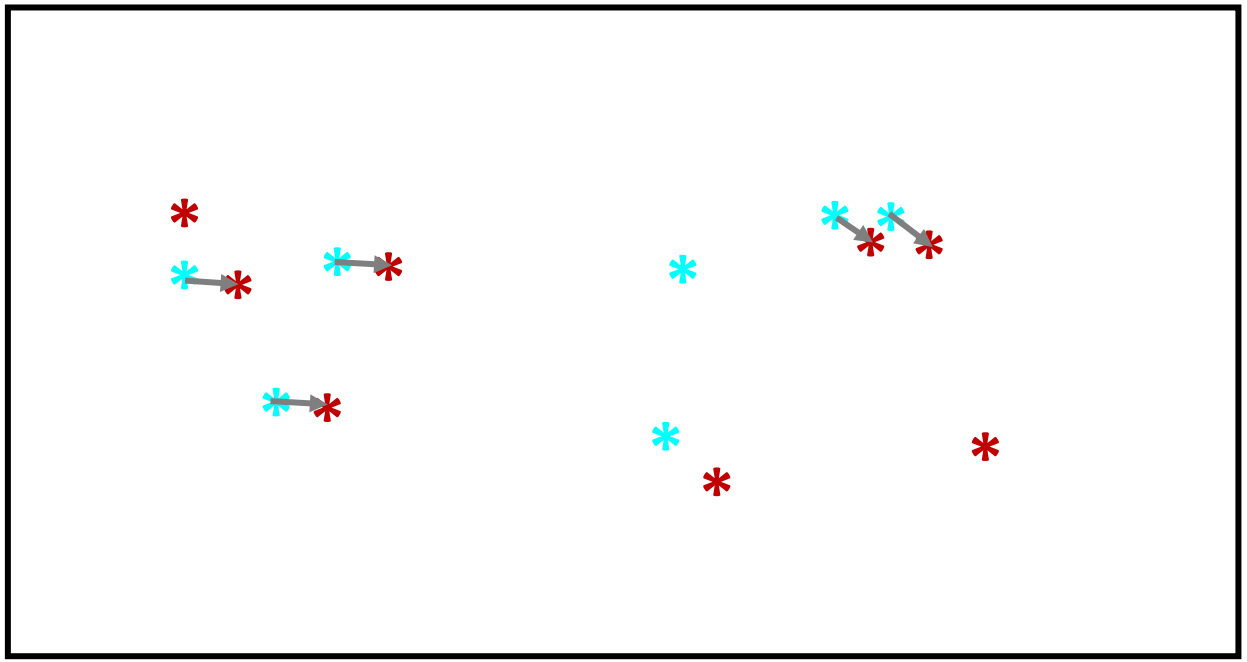
STAT

minimize (the differences of displacement vectors within a neighborhood)

Two necessary parameters

How does ‘Stay Together Align Together’ work





Initialization

Output

Update:

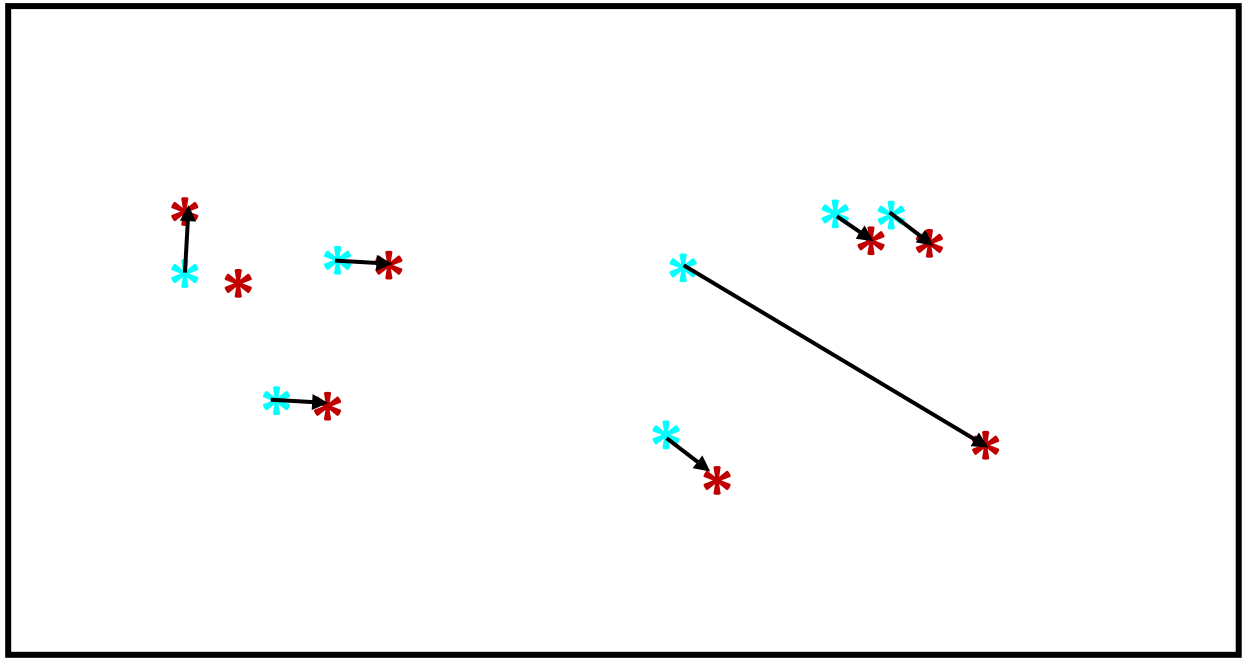
1. minimize **cost** m =the difference of displacement vectors within a neighborhood (radius **R**);
2. **cost** $m <$ **threshold** θ

Two necessary parameters

The next few slides show how STAT works in more detail

How does ‘Stay Together Align Together’ work

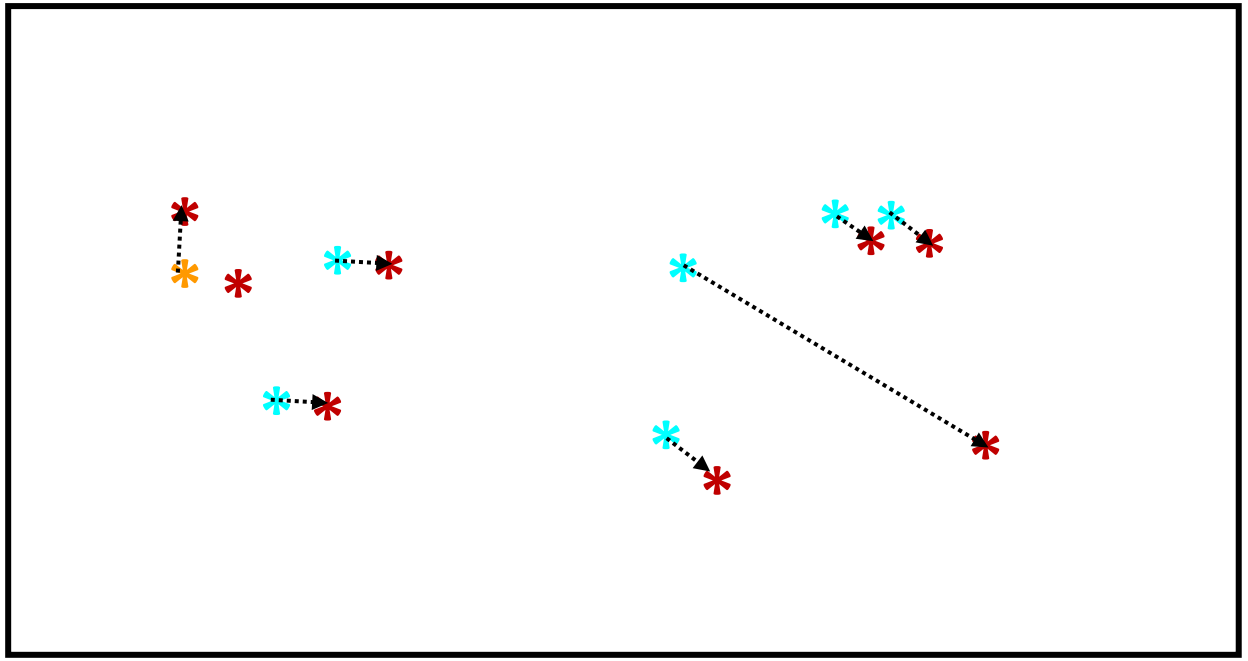
Start with a guess: choose close neighbors



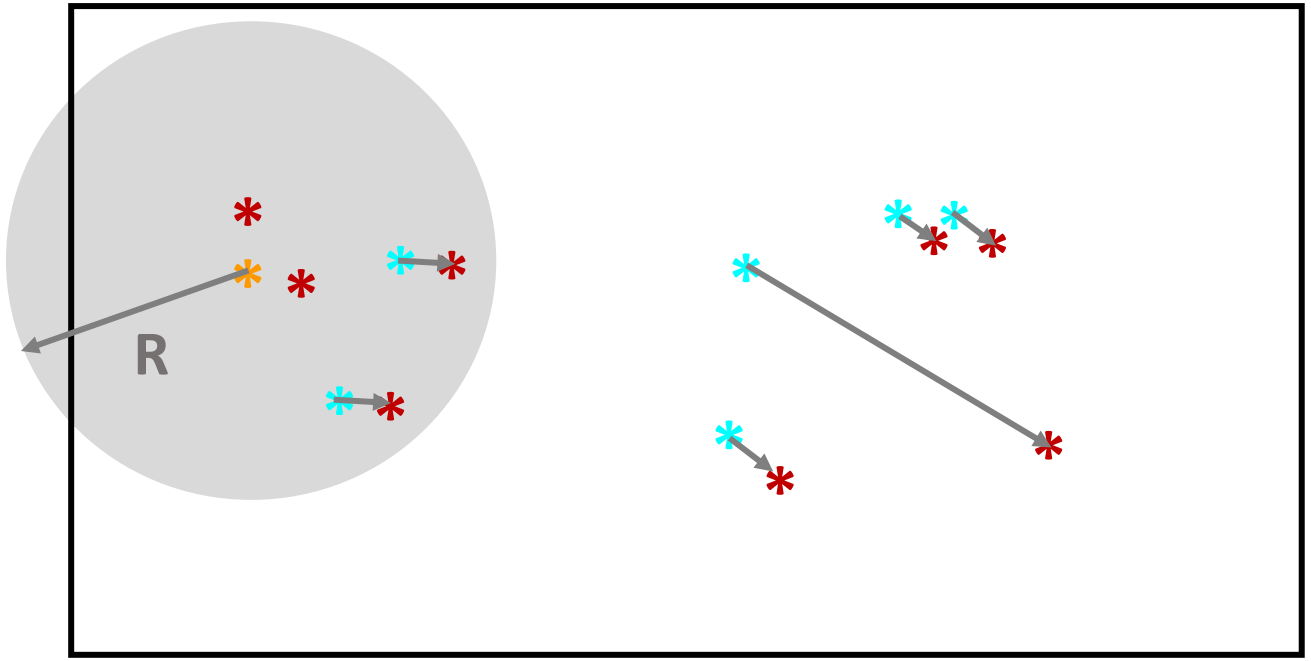
minimize the sum of displacement vector lengths

(solved by Hungarian Algorithm)

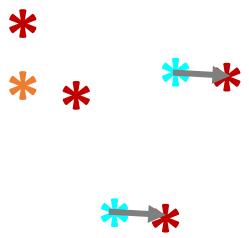
How does ‘Stay Together Align Together’ work
Update



How does ‘Stay Together Align Together’ work
Update

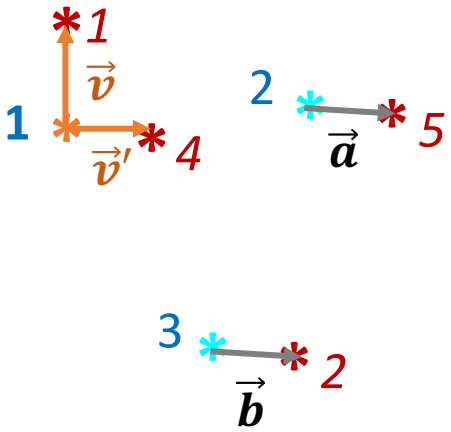


How does ‘Stay Together Align Together’ work
Update



How does ‘Stay Together Align Together’ work

Update



- Enumerate **cost** for each possible match

$$\text{cost} = E(proposed\ movements - neighbor\ movements)$$

if match to neuron 1

$$\text{cost}\ (1) = \frac{\|\vec{v}-\vec{a}\|+\|\vec{v}-\vec{b}\|}{2}$$

if match to neuron 4

$$\text{cost}(4) = \frac{\|\vec{v}'-\vec{a}\|+\|\vec{v}'-\vec{b}\|}{2}$$

How does ‘Stay Together Align Together’ work

Update

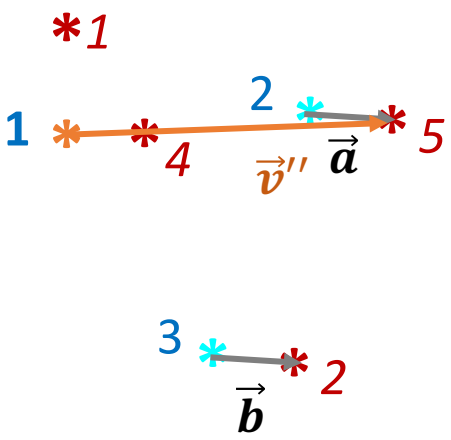
Enumerate **costs** in all possible matches

$$\text{cost}(1) = \frac{\|\vec{v}-\vec{a}\|+\|\vec{v}-\vec{b}\|}{2}$$

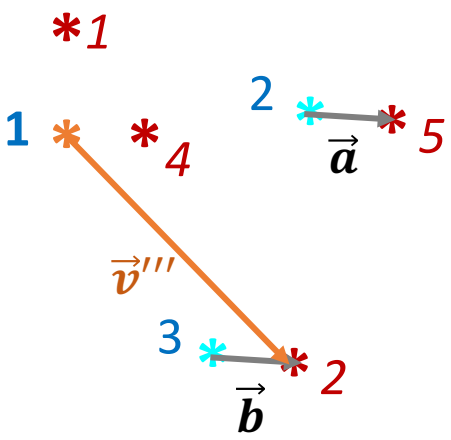
$$\text{cost}(4) = \frac{\|\vec{v}\prime-\vec{a}\|+\|\vec{v}\prime-\vec{b}\|}{2}$$

if match to neuron 5

$$\text{cost}(5) = \frac{\|\vec{v}\prime\prime-\vec{a}\|+\|\vec{v}\prime\prime-\vec{b}\|}{2}$$



How does ‘Stay Together Align Together’ work
Update



- Enumerate **costs** in all possible matches

$$\text{cost}(1) = \frac{\|\vec{v}-\vec{a}\|+\|\vec{v}-\vec{b}\|}{2}$$

$$\text{cost}(4) = \frac{\|\vec{v}'-\vec{a}\|+\|\vec{v}'-\vec{b}\|}{2}$$

$$\text{cost}(5) = \frac{\|\vec{v}''-\vec{a}\|+\|\vec{v}''-\vec{b}\|}{2}$$

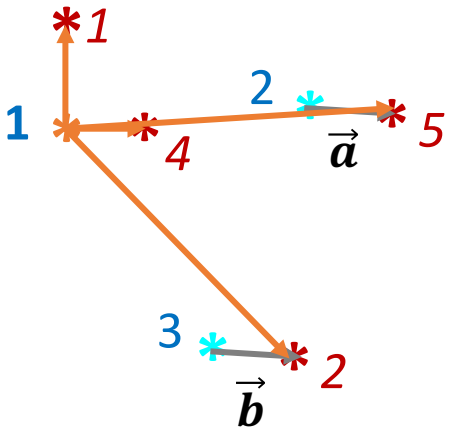
$$\text{cost}(2) = \frac{\|\vec{v}'''-\vec{a}\|+\|\vec{v}'''-\vec{b}\|}{2}$$

Define if match to neuron 0 (no match)

$$\text{cost}(0) = \theta$$

How does ‘Stay Together Align Together’ work

Update



- Enumerate **costs** in all possible matches

$$\text{cost}(1) = \frac{\|\vec{v}-\vec{a}\|+\|\vec{v}-\vec{b}\|}{2}$$

$$\text{cost}(4) = \frac{\|\vec{v}\prime-\vec{a}\|+\|\vec{v}\prime-\vec{b}\|}{2}$$

$$\text{cost}(5) = \frac{\|\vec{v}\prime\prime-\vec{a}\|+\|\vec{v}\prime\prime-\vec{b}\|}{2}$$

$$\text{cost}(2) = \frac{\|\vec{v}\prime\prime\prime-\vec{a}\|+\|\vec{v}\prime\prime\prime-\vec{b}\|}{2}$$

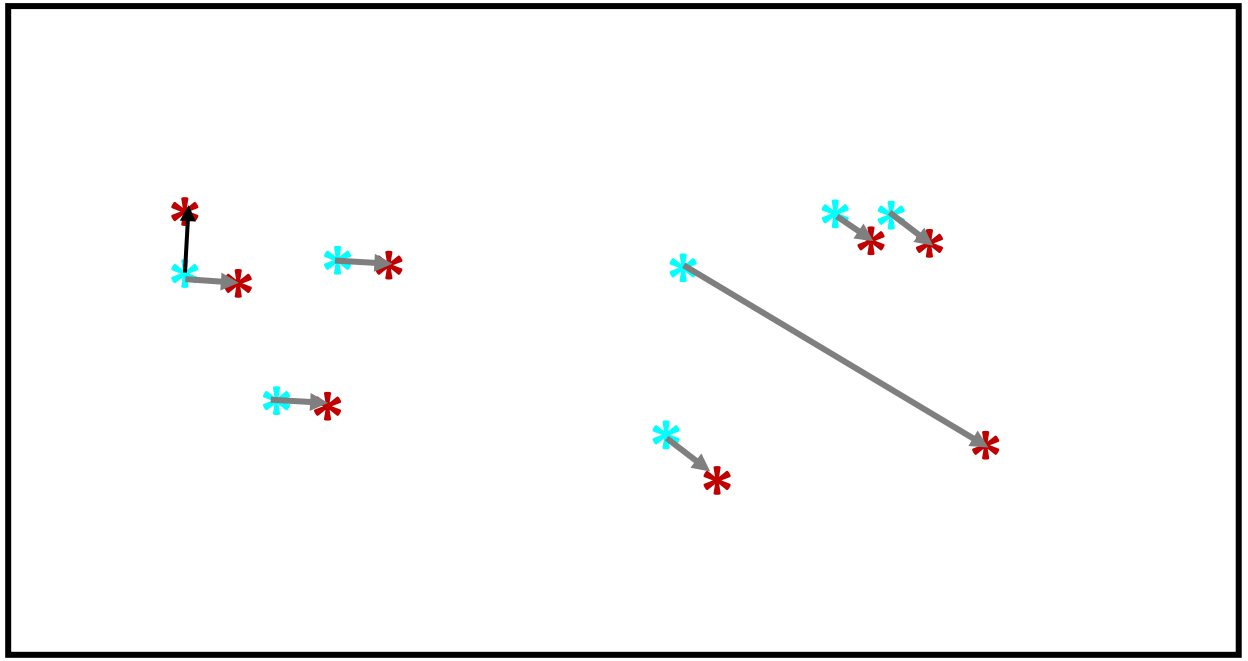
$$\text{cost}(0) = \theta$$

- Choose the match that minimizes the cost

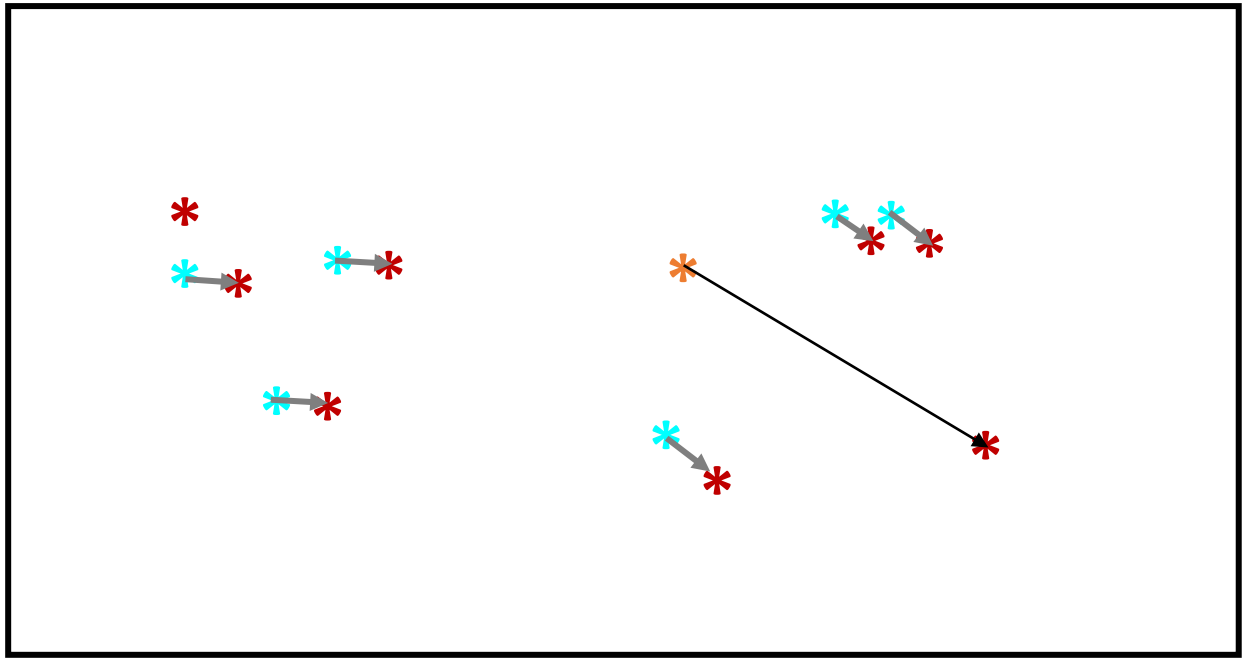
$$\text{Neuron } 1\text{'s match} = \mathbf{argmin}\,\text{cost(j)}\,, \boldsymbol{j} \in \{\mathbf{0}, \mathbf{1}, \mathbf{2}, \mathbf{4}, \mathbf{5}\}$$

$$= 4$$

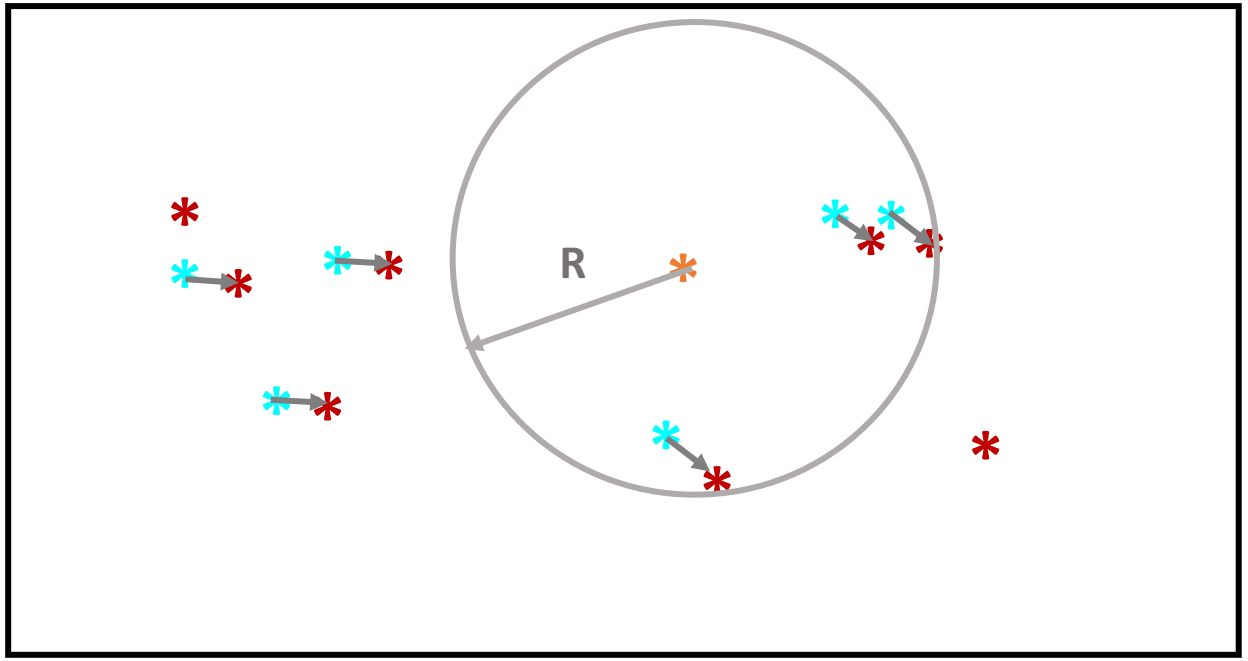
How does ‘Stay Together Align Together’ work
Update



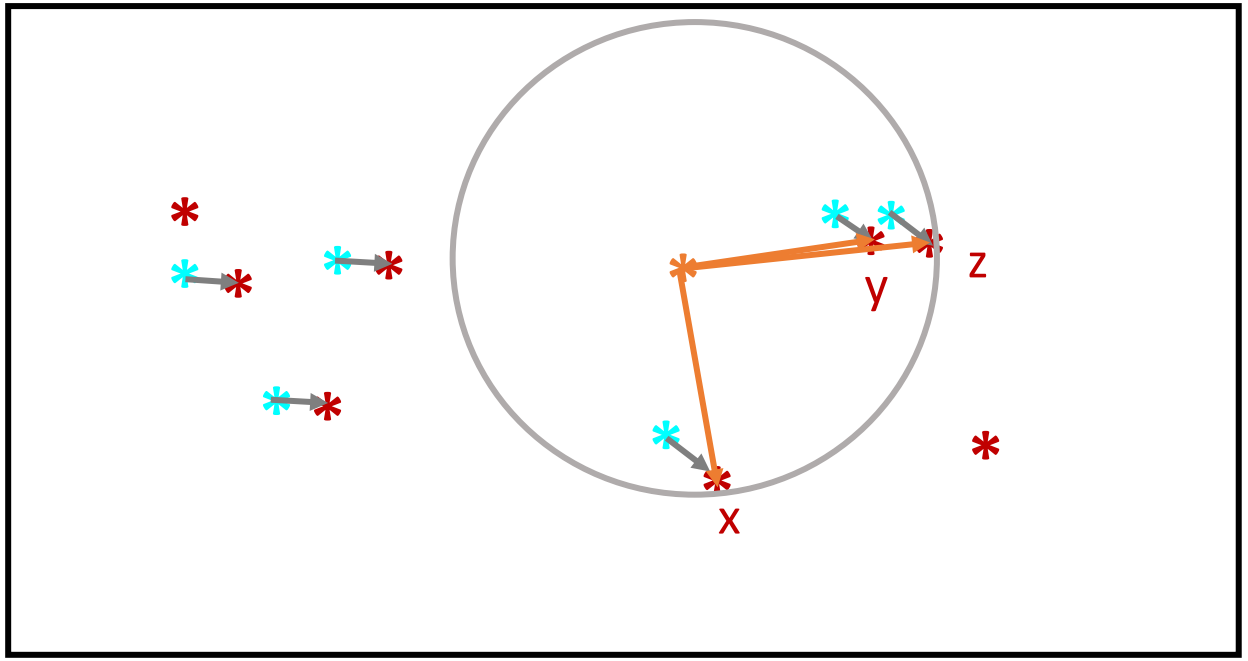
How does ‘Stay Together Align Together’ work
Keep Updating



How does ‘Stay Together Align Together’ work
Keep Updating

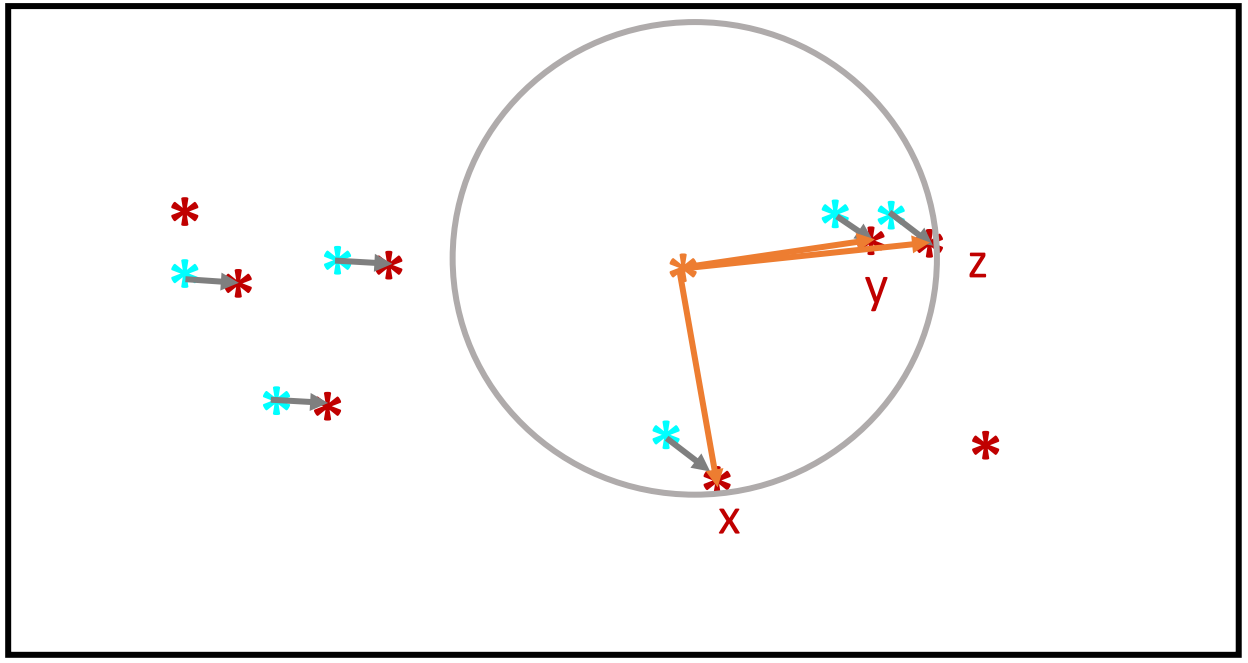


How does ‘Stay Together Align Together’ work
Keep Updating



$$\text{match} = \mathbf{argmin}\,\text{cost(j)}\,, \boldsymbol{j} \in \{\mathbf{0}, \mathbf{x}, \mathbf{y}, \mathbf{z}\}$$

How does ‘Stay Together Align Together’ work
Keep Updating

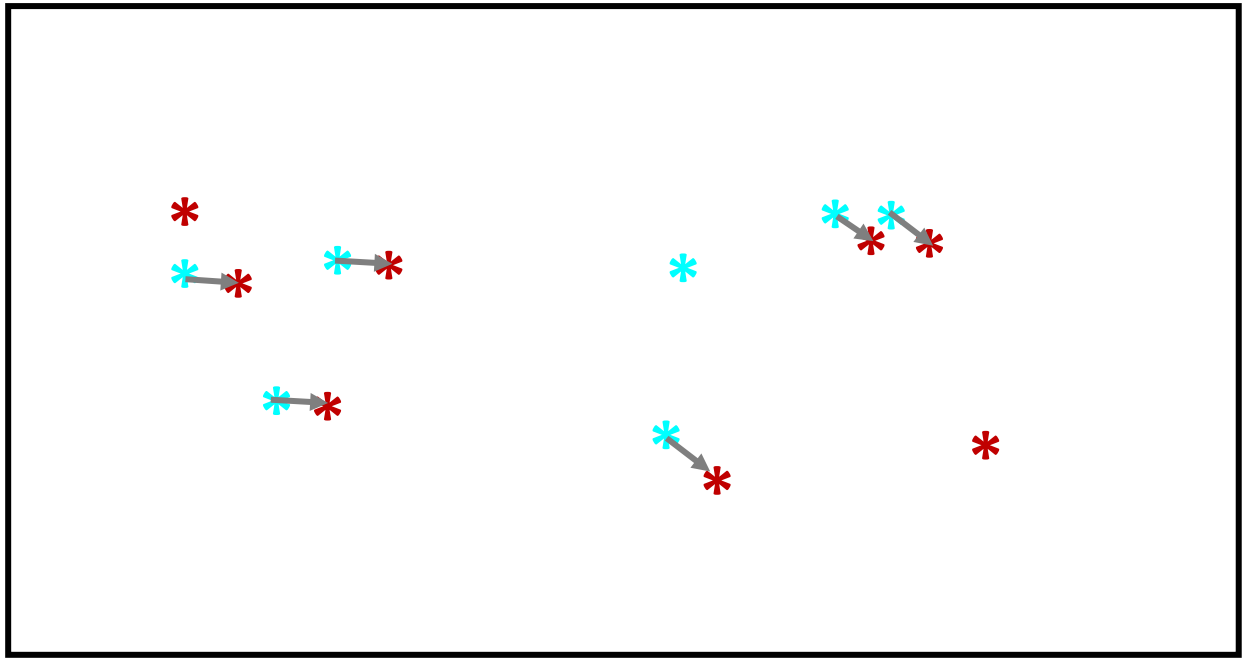


$$\text{match} = \mathbf{argmin}\,\text{cost(j)}\,, \boldsymbol{j} \in \{\mathbf{0}, \mathbf{x}, \mathbf{y}, \mathbf{z}\}$$

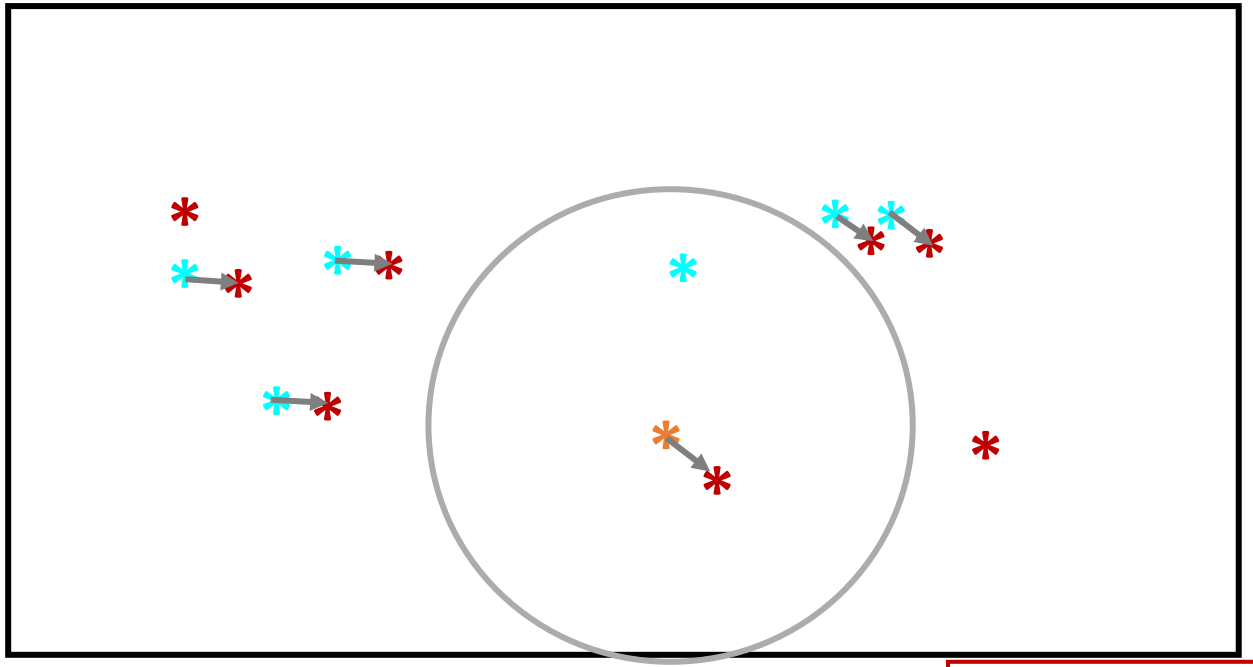
$$= 0$$

Null case ①: No good matches

How does ‘Stay Together Align Together’ work
Keep Updating



How does ‘Stay Together Align Together’ work
Keep Updating



$$\text{cost} = E(proposed\ movements - neighbor\ movements)$$

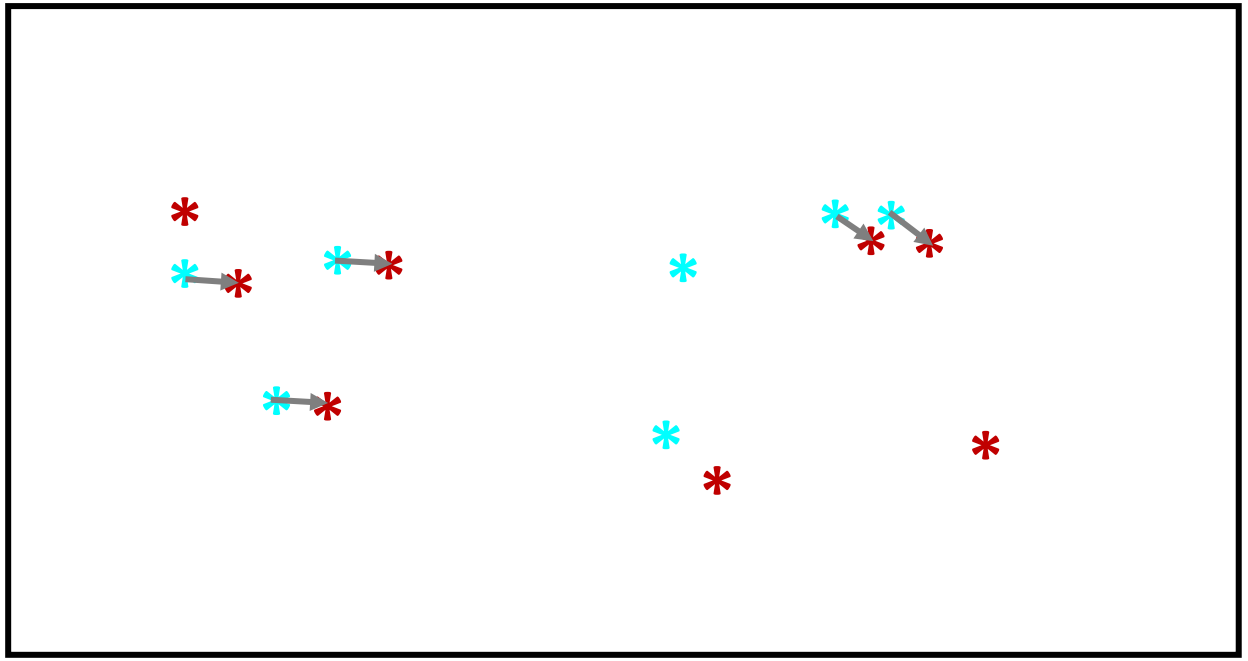
$$\text{match} = \mathbf{argmin}\,\text{cost(j)}\,, \boldsymbol{j} \in \{\mathbf{0}\}$$

$$= 0$$

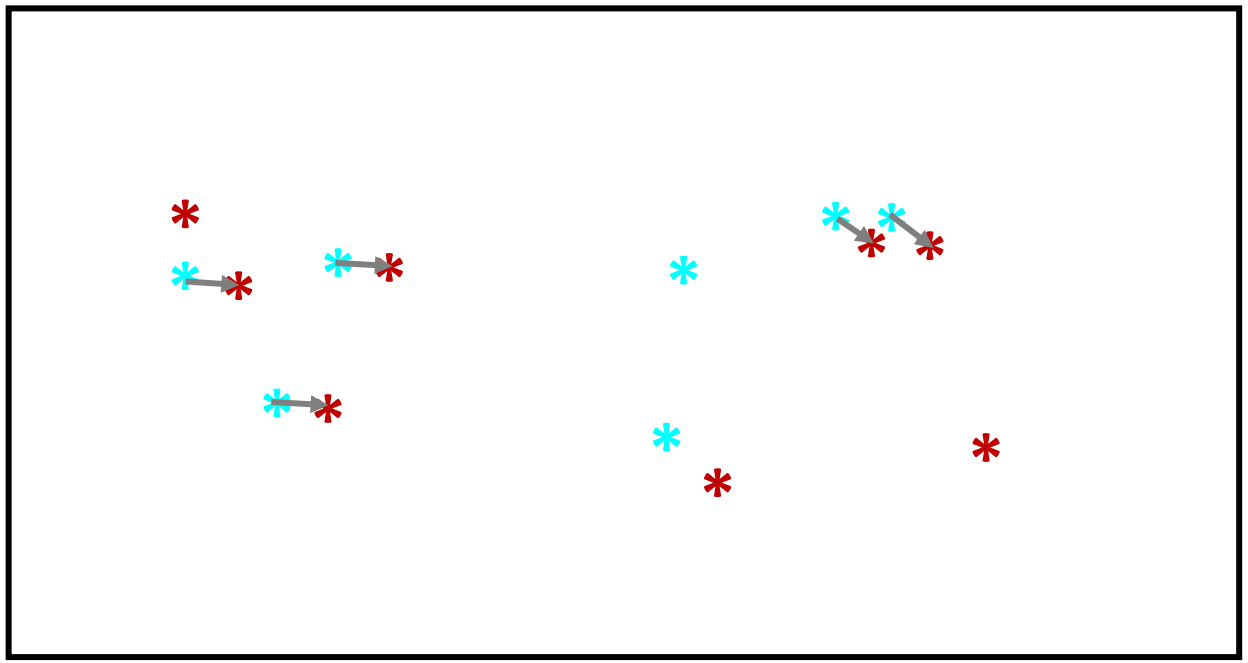
$\varnothing$

Null case ②: No neighbors with matches

How does ‘Stay Together Align Together’ work
Keep Updating



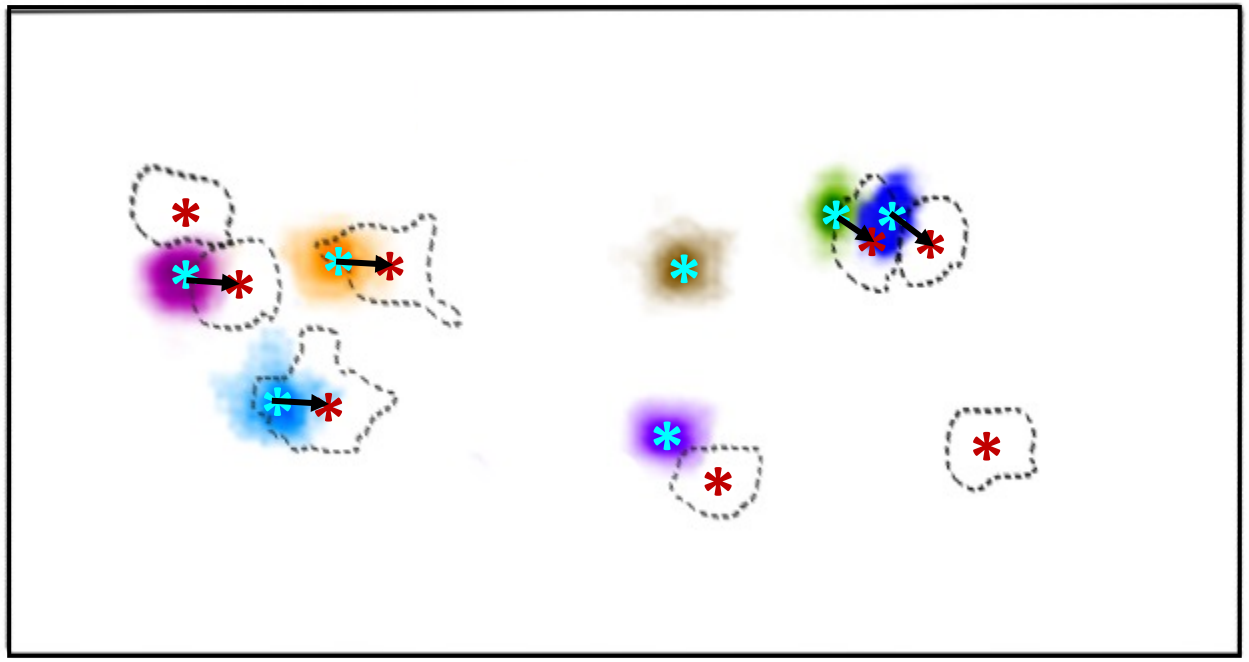
How does ‘Stay Together Align Together’ work



Summary:
Using **local consistency**, we can
(1) Pick out neurons unique to each session
(2) Find their matches for those common neurons.

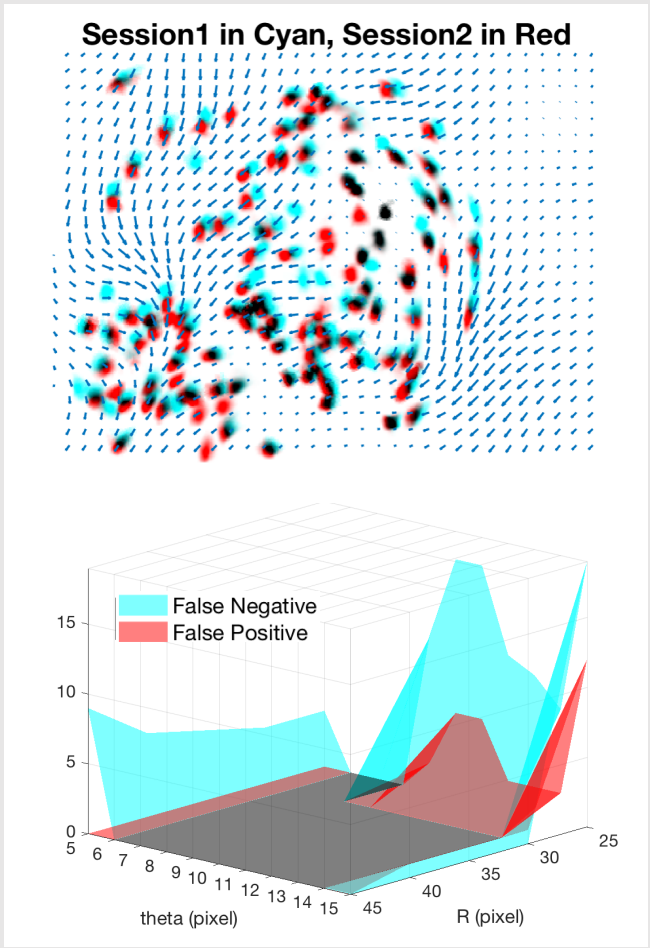
Also extend to 3D data easily!

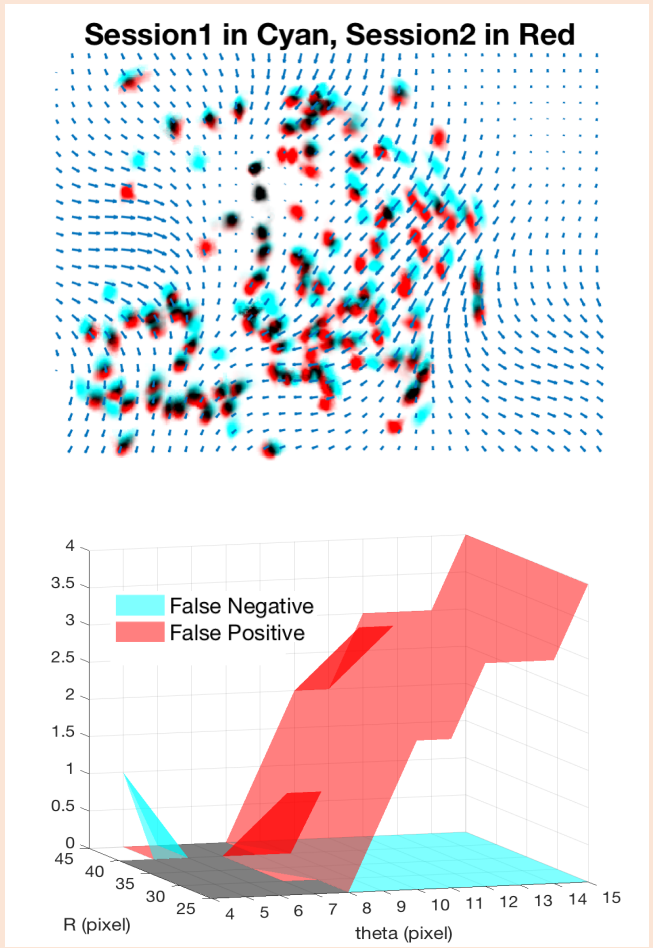
After ‘Stay Together Align Together’

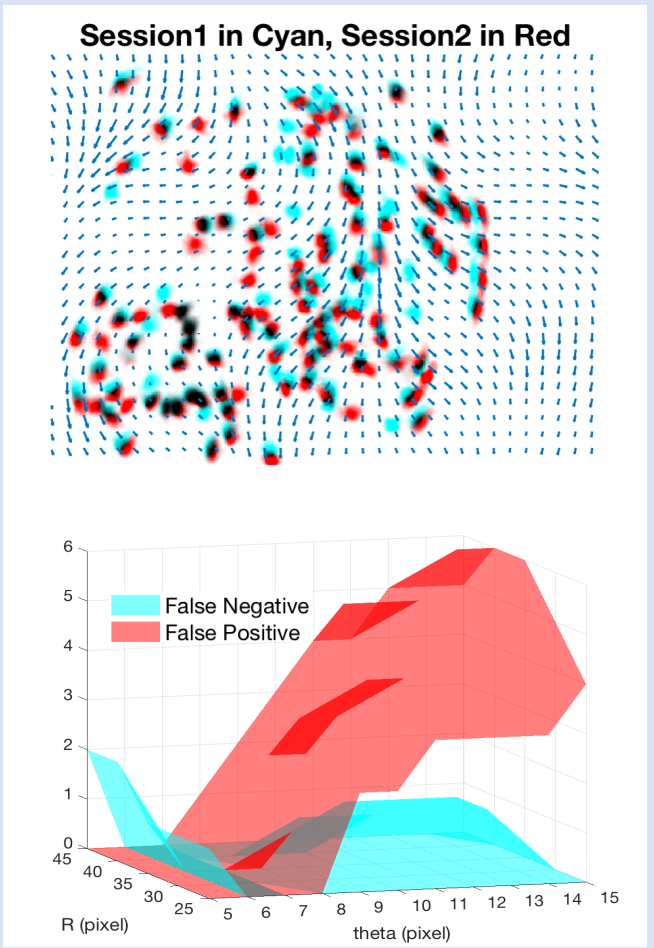


Neuron shape information can be used as an independent piece of information for sanity check

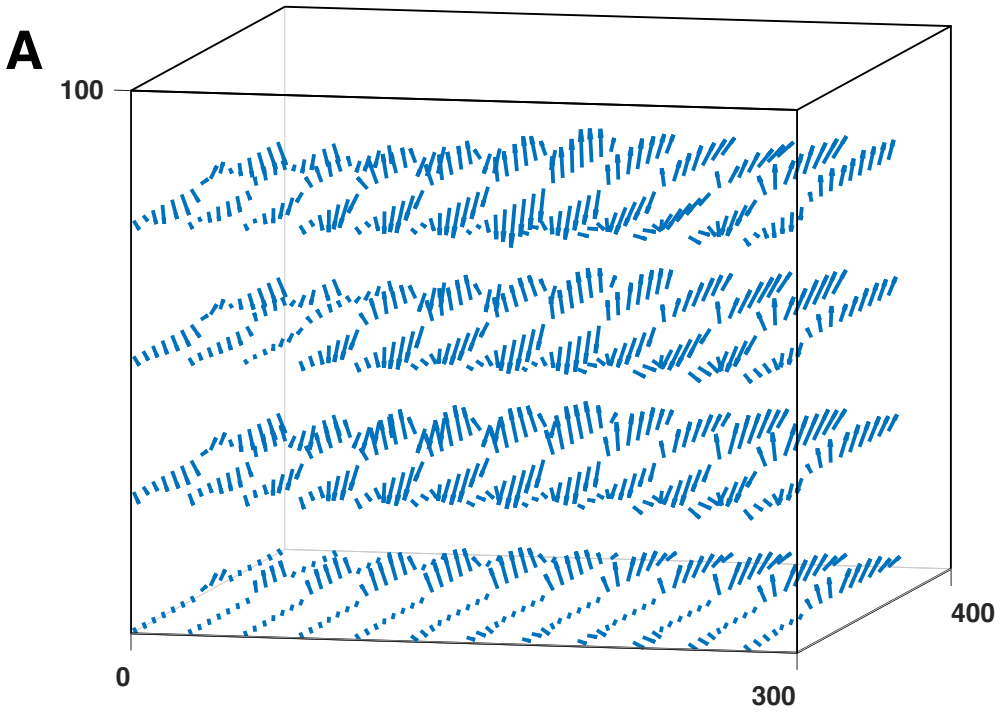
Testing STAT on simulated data

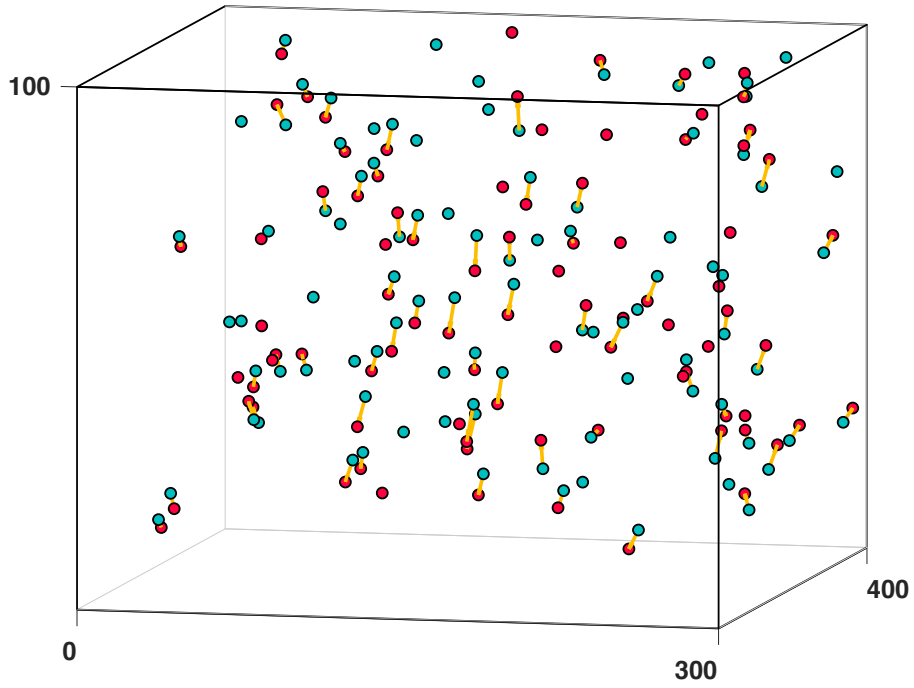


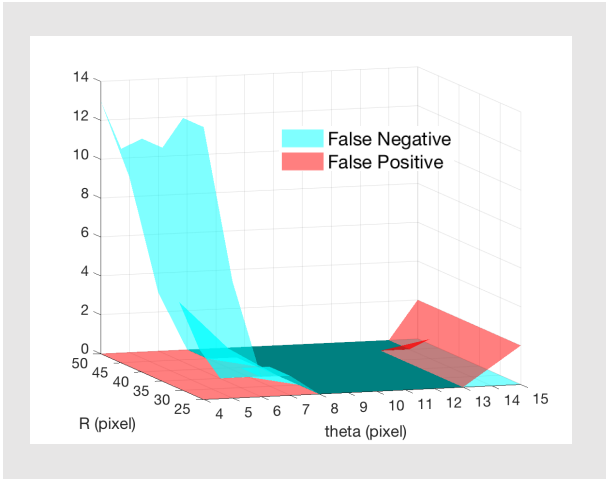


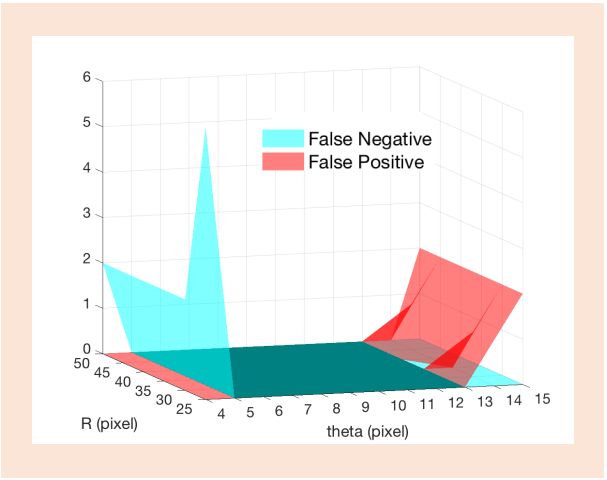


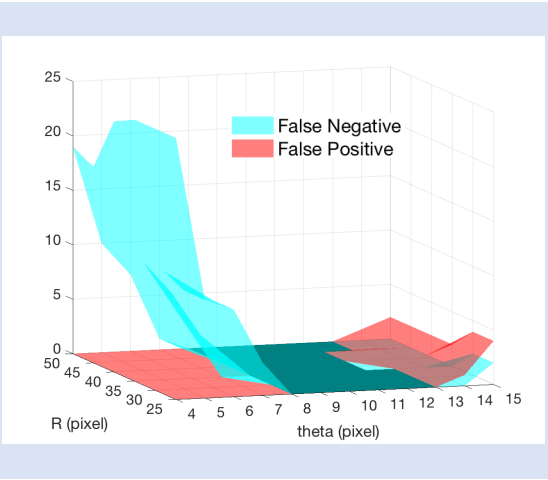
Testing STAT on simulated **3D** data





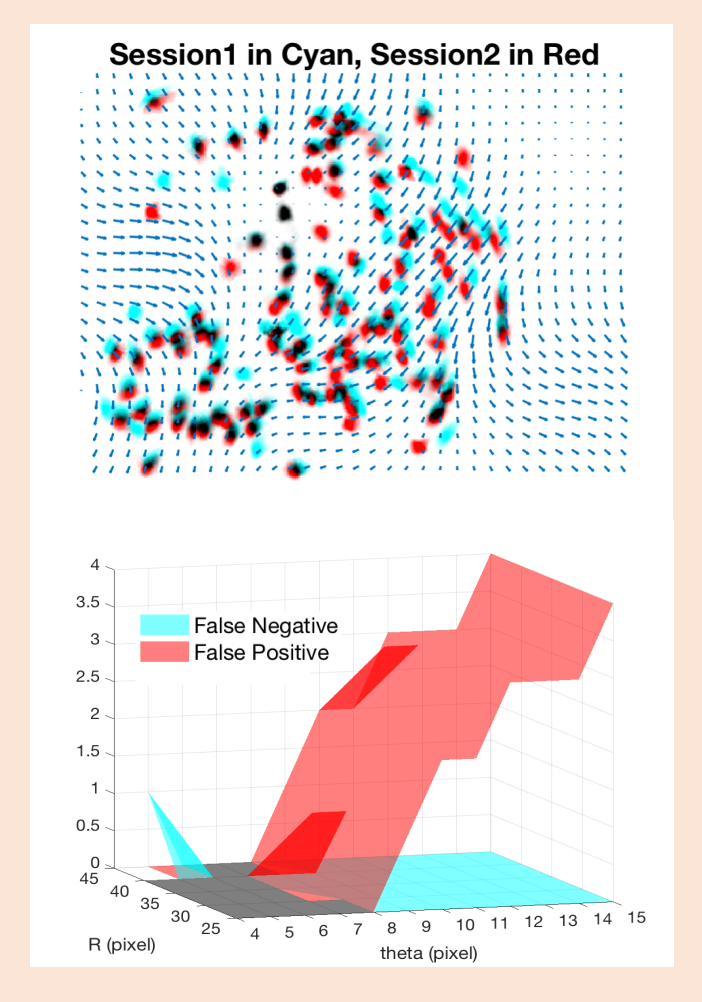


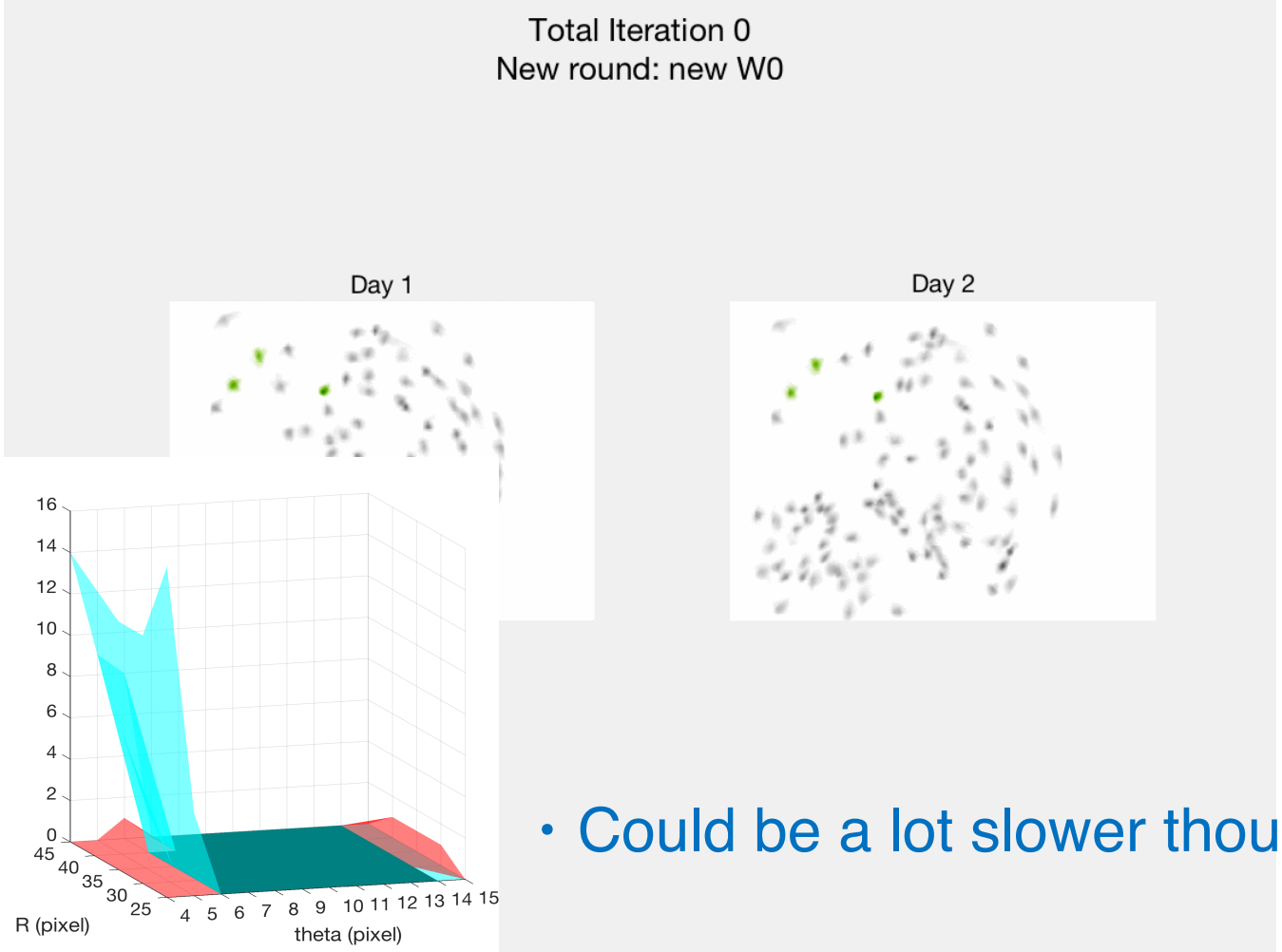




What if initialization fails?

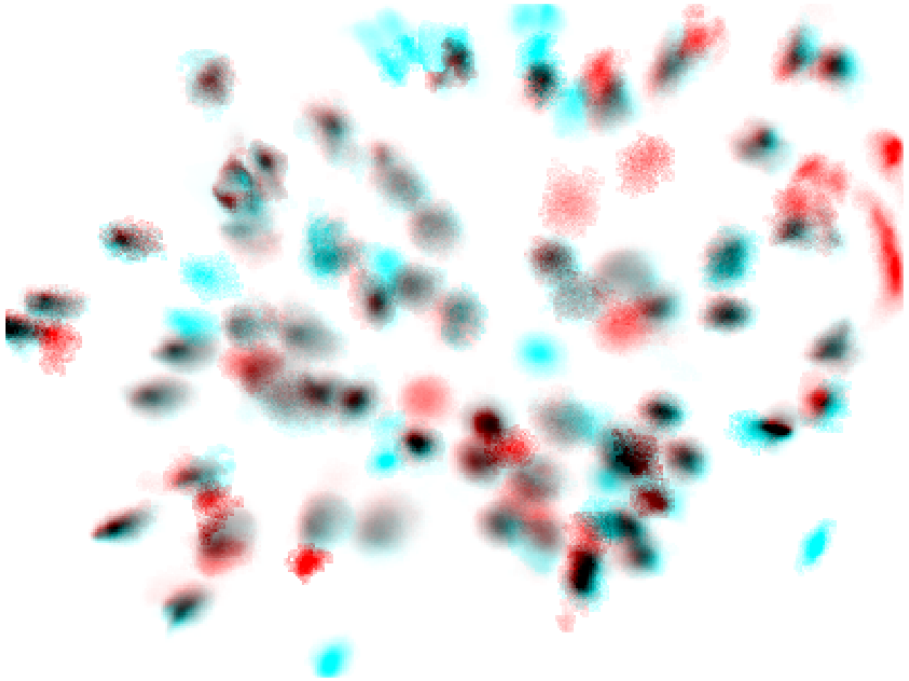
- Handpick a few and let the algorithm propagate



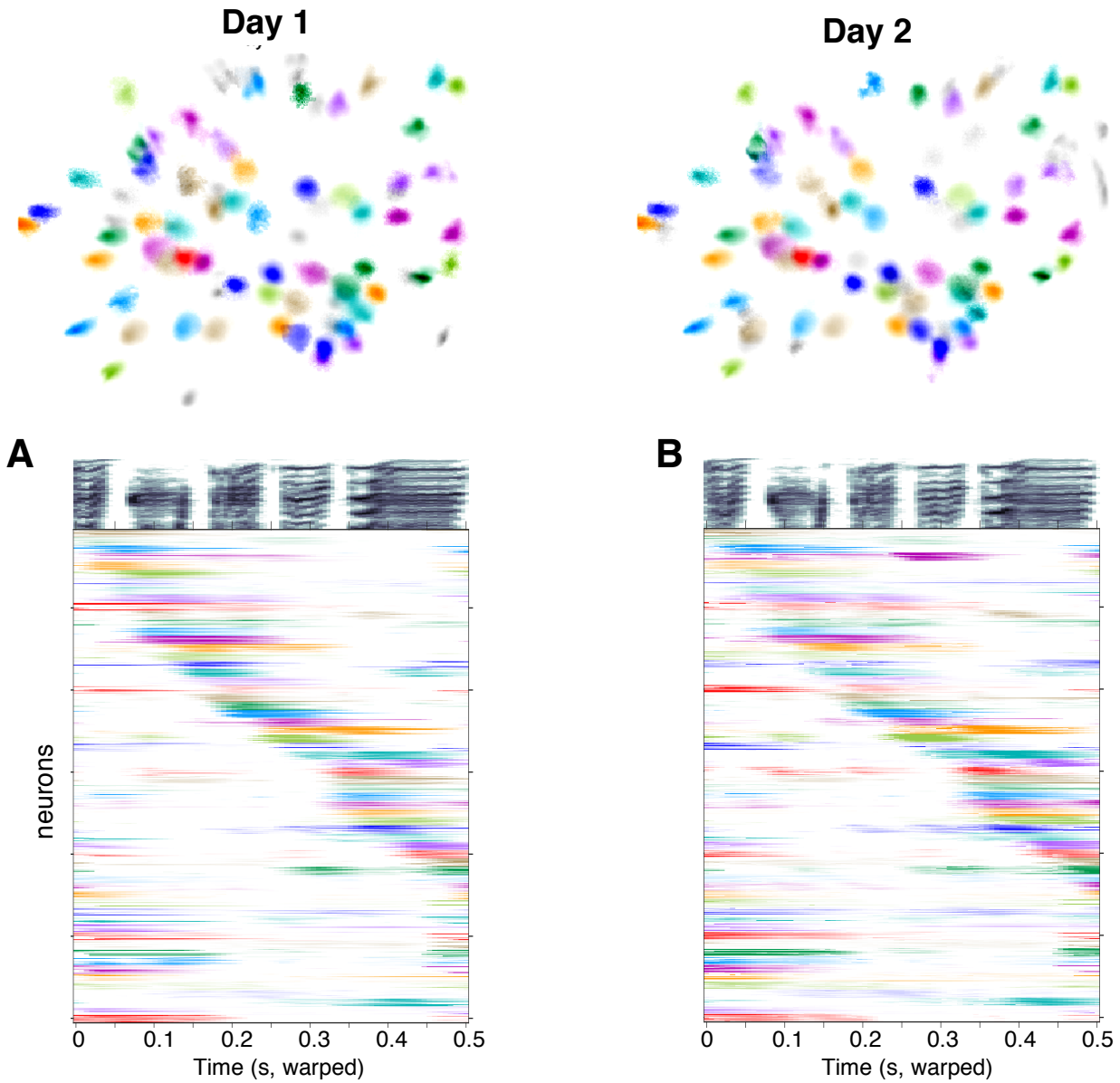


- Could be a lot slower though!

Testing STAT on real songbird data

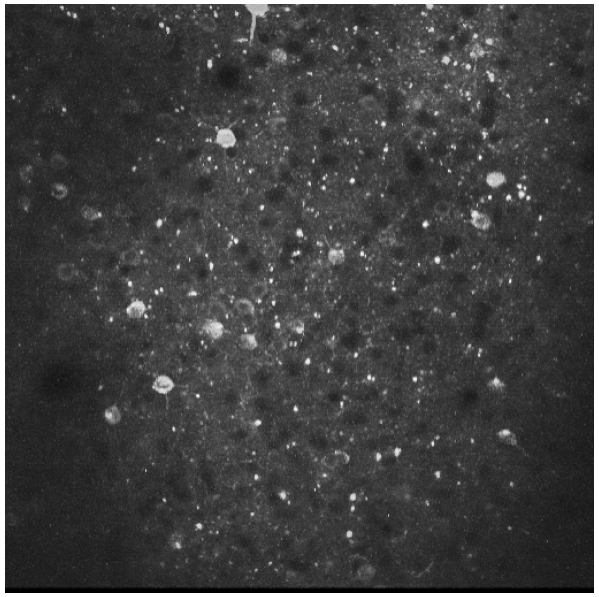


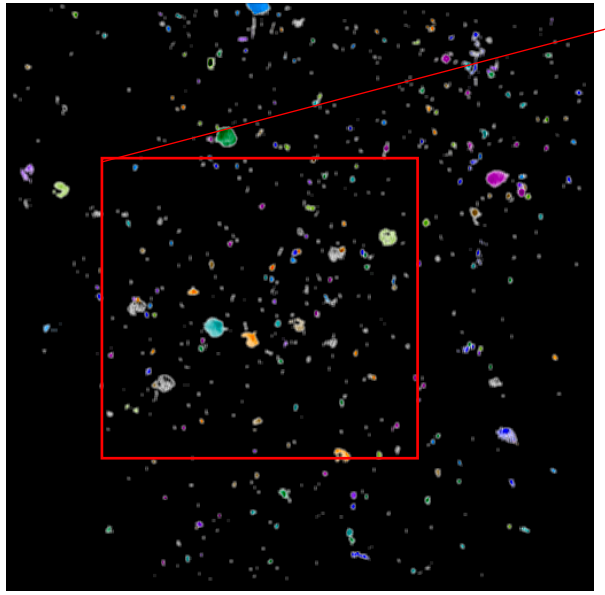
Testing STAT on real songbird data



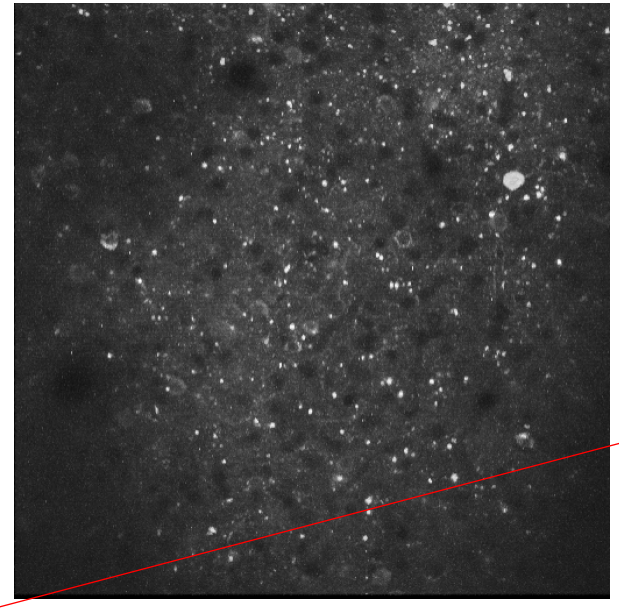
Testing STAT on dense 2p data

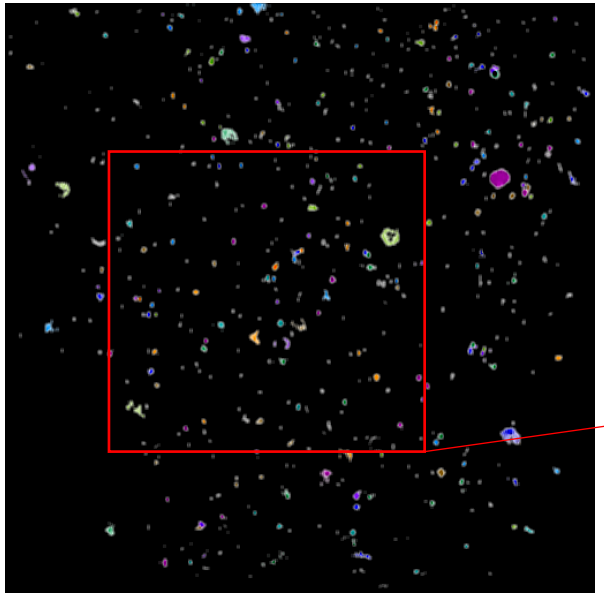
Session A

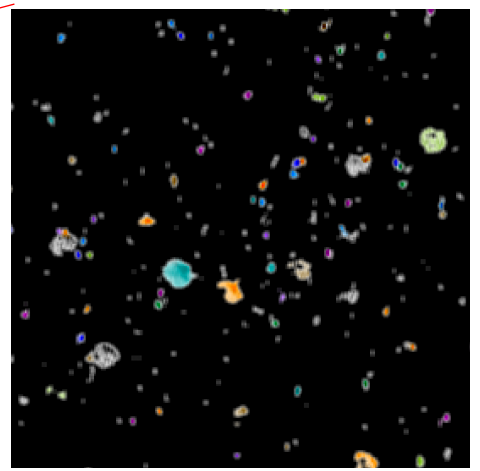


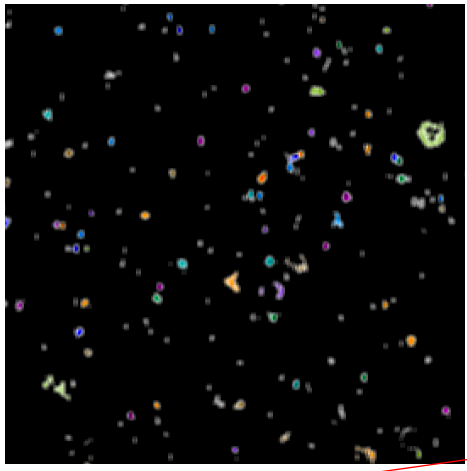


Session B









Dataset: Allen Brain Observatory dataset ID: 661437140 (Session A), 662351346 (Session B), ~1000 frames from each session