Segmenting Goal-Directed Animal Behavior

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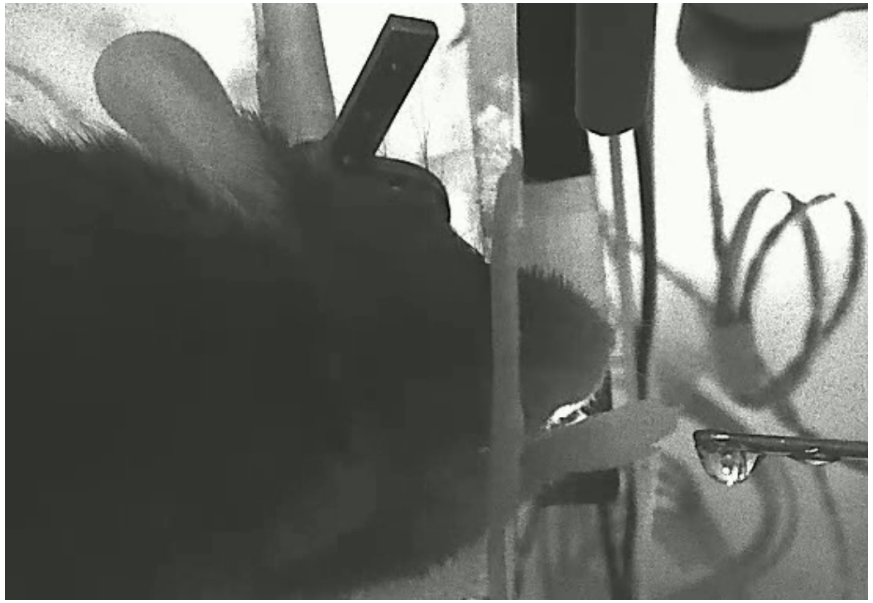
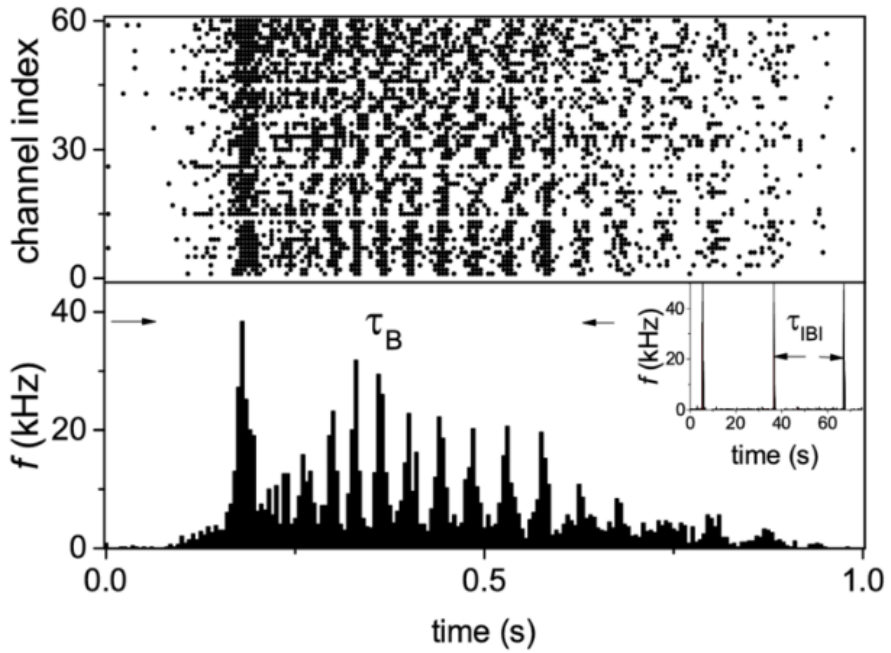
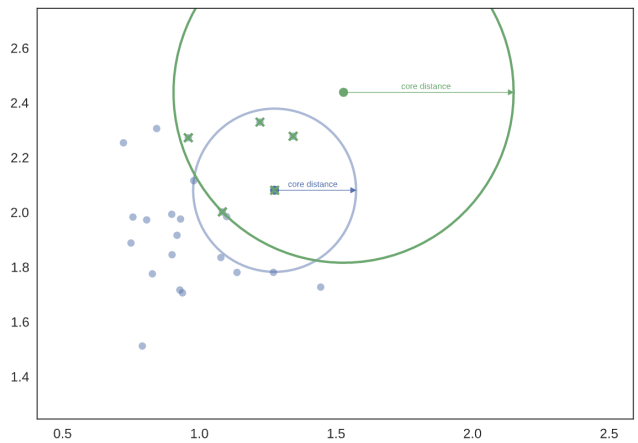
Problem Description and Significance

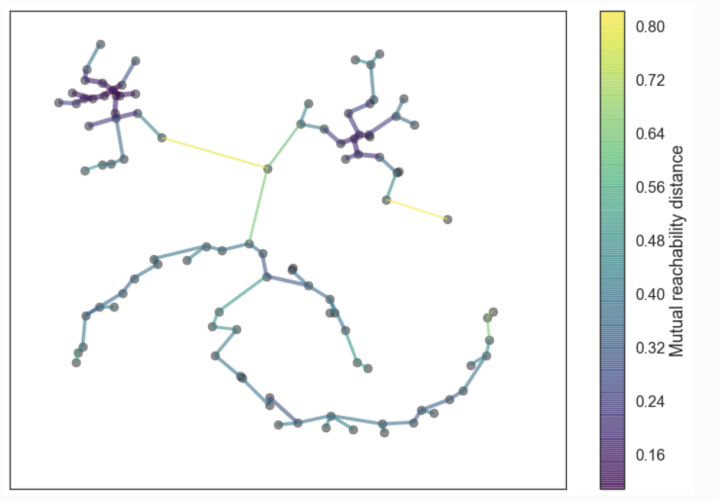




Current State of the Art (1)

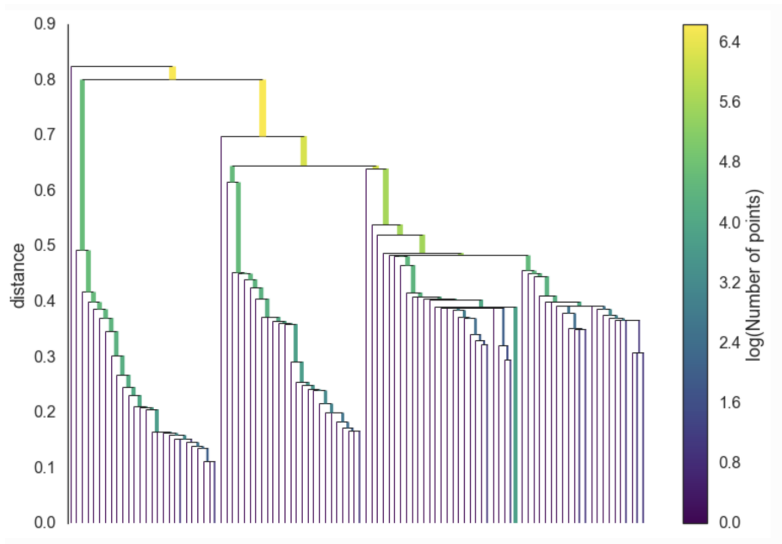
B-SOiD uses Hierarchical Density-Based Spatial Clustering of Applications with Noise (HDBSCAN)

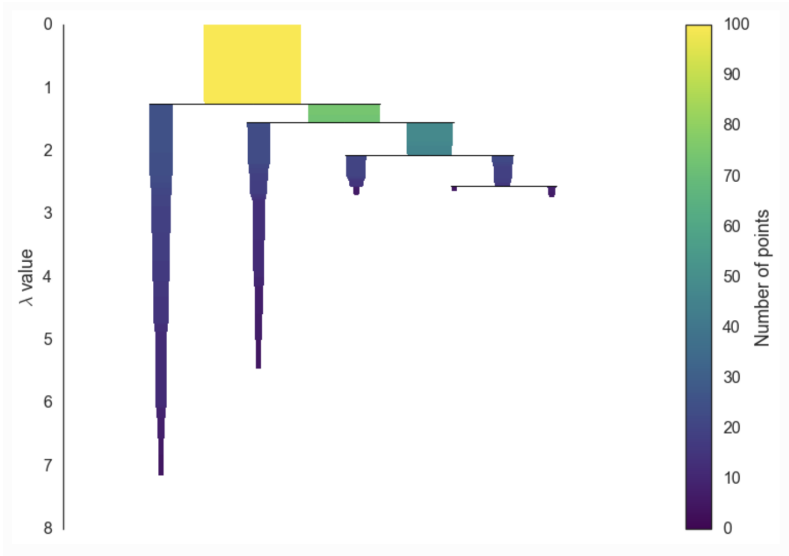




Current State of the Art (2)

B-SOiD uses Hierarchical Density-Based Spatial Clustering of Applications with Noise (HDBSCAN)





Current State of the Art (3)

Problems with HDBSCAN

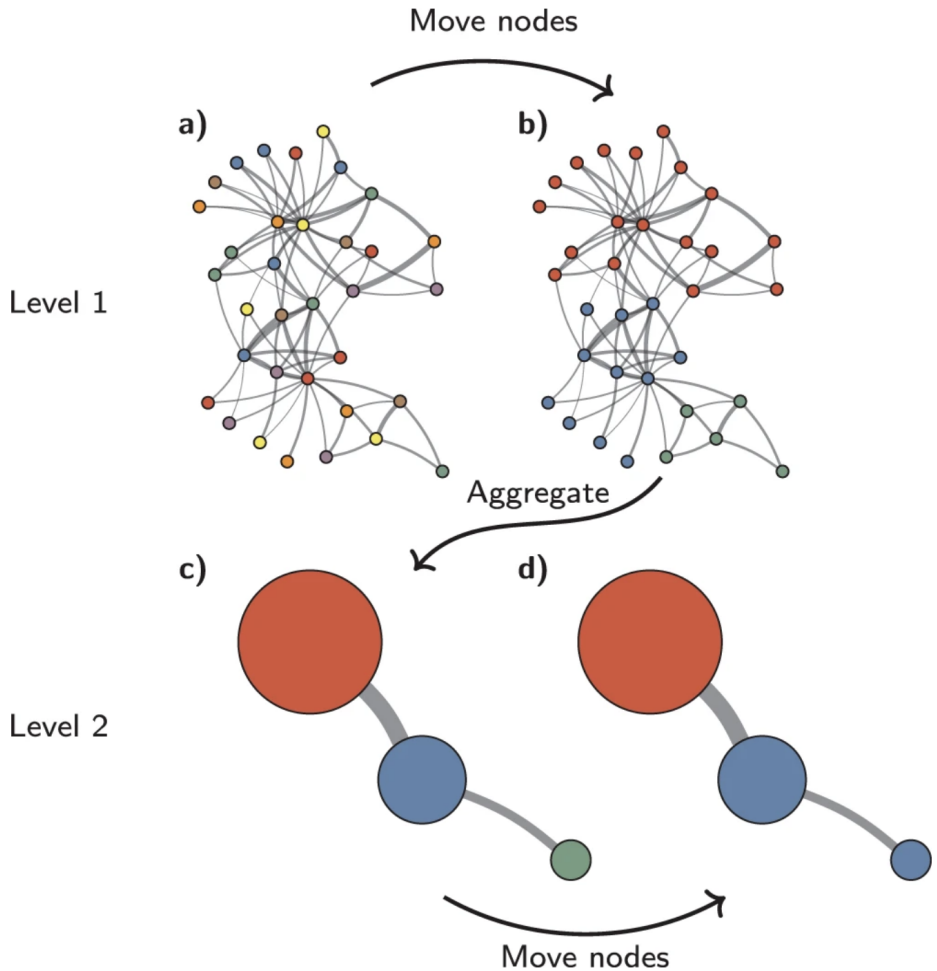
1. We must choose the value for hyperparameter minimum cluster size. This parameter is influences how many clusters are output, and is very sensitive. The number of clusters either is too few (think 2 clusters) and doesn't allow meaningful interpretation, or outputs too many (think 20 clusters) and segments larger behaviors we want for interpretation into sub-behaviors.
2. The timing of the transitions between behaviors is important to get exactly right, as the transitions between different behaviors are going to be used as the flashpoints when synced with the brain activity data.

Methodology (1)

As we want to improve upon B-SOiD to achieve better, more interpretable clustering...

- We can frame our problem as a community detection problem. As we have too many sub-behavior clusters and as we want larger behavior clusters, we can identify communities of the sub-behaviors and collapse them into interpretable behaviors
- We looked at leading community detection algorithms and found the Louvain and Leiden community detection algorithms

Methodology (2)



Louvain algorithm. The Louvain algorithm starts from a singleton partition in which each node is in its own community (**a**). The algorithm moves individual nodes from one community to another to find a partition (**b**). Based on this partition, an aggregate network is created (**c**). The algorithm then moves individual nodes in the aggregate network (**d**). These steps are repeated until the quality cannot be increased further.

Louvain:

Methodology (3)

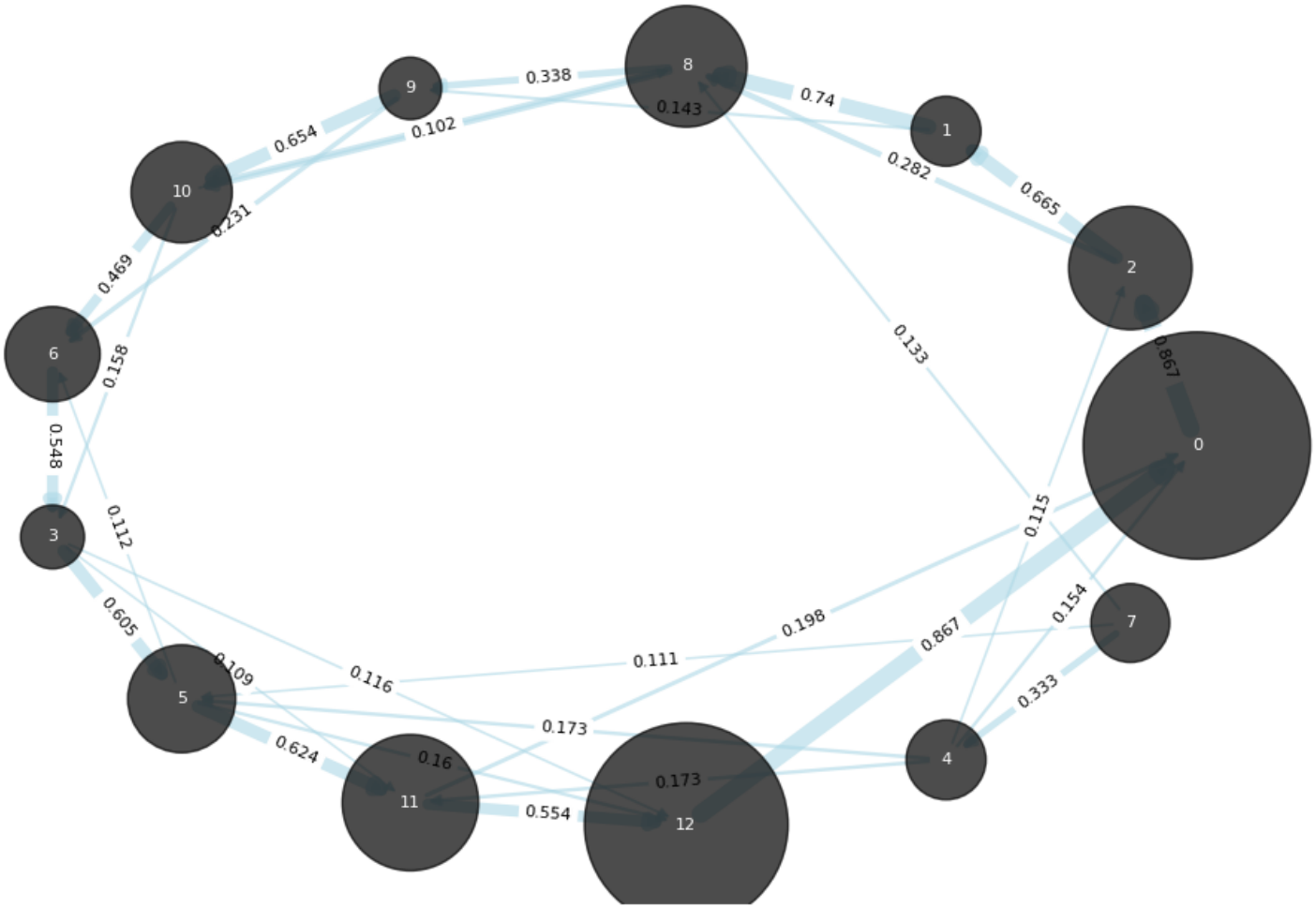
Our Methodology:

- Density of c $= e_c$
- Expected density of c adjusted by gamma $= \gamma \frac{K_c^2}{2m}$

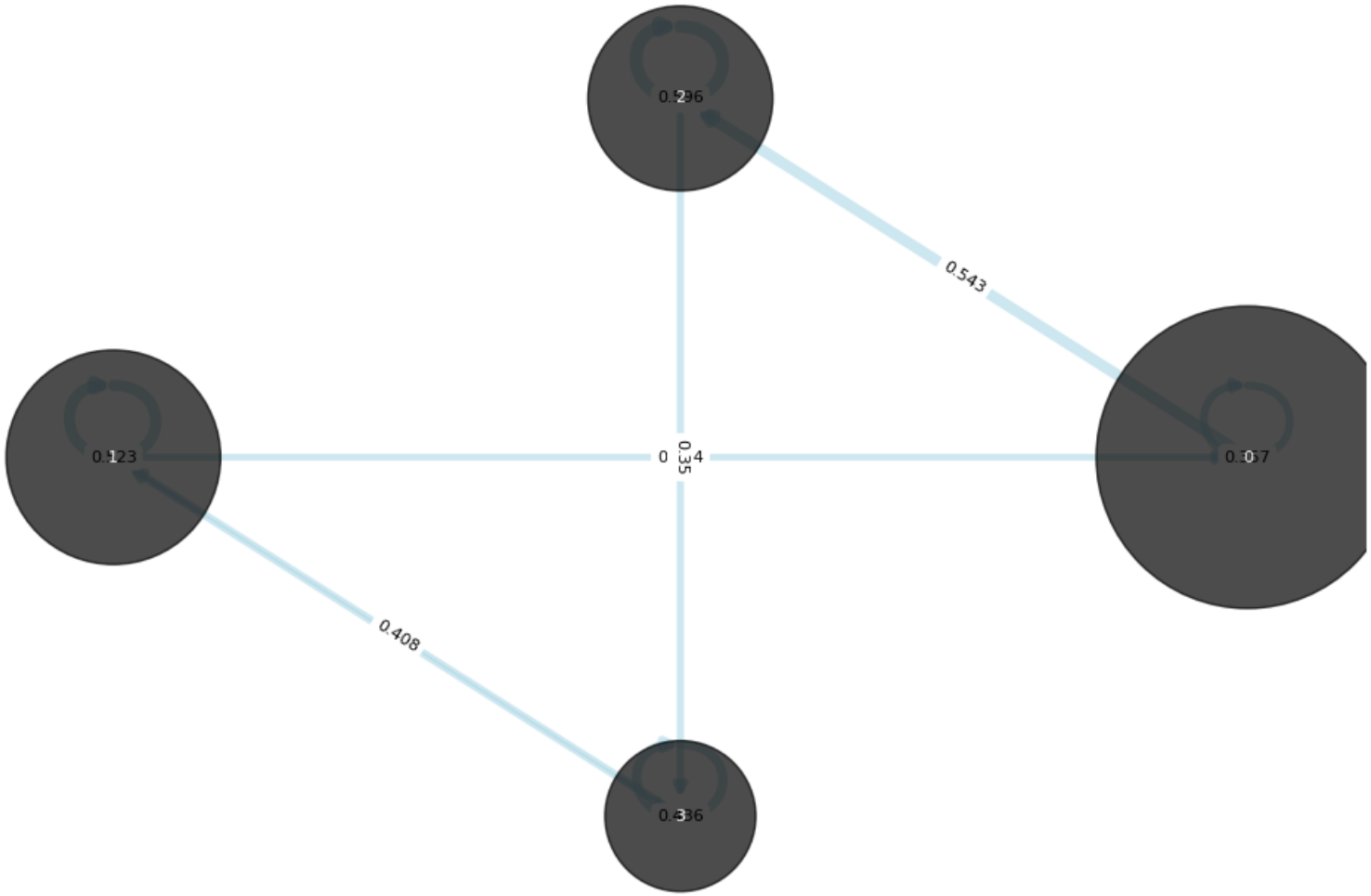
$$H = \frac{1}{2m} \sum_c (e_c - \gamma \frac{K_c^2}{2m})$$

- Run Louvain with a sliding value of gamma to produce graph new clusters
- We want 4 main behaviors - aiming, reaching, retracting, drinking - so we only consider graphs with 4 nodes
- We observe these behaviors happening in a strict sequential order, so we want the end graph to have a strong cycle of length 4

Clustering from B-SOiD



Clustering from Louvain

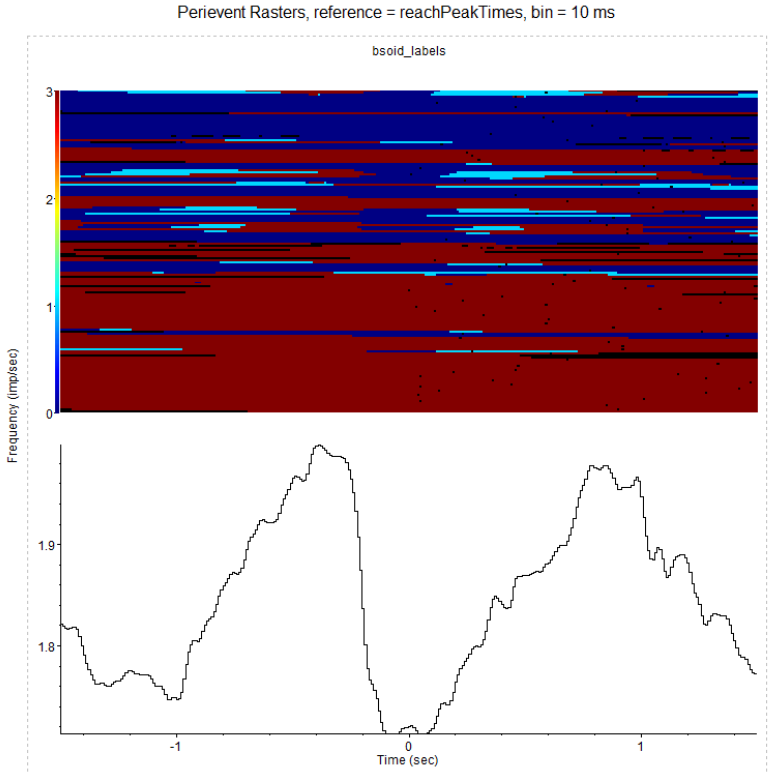


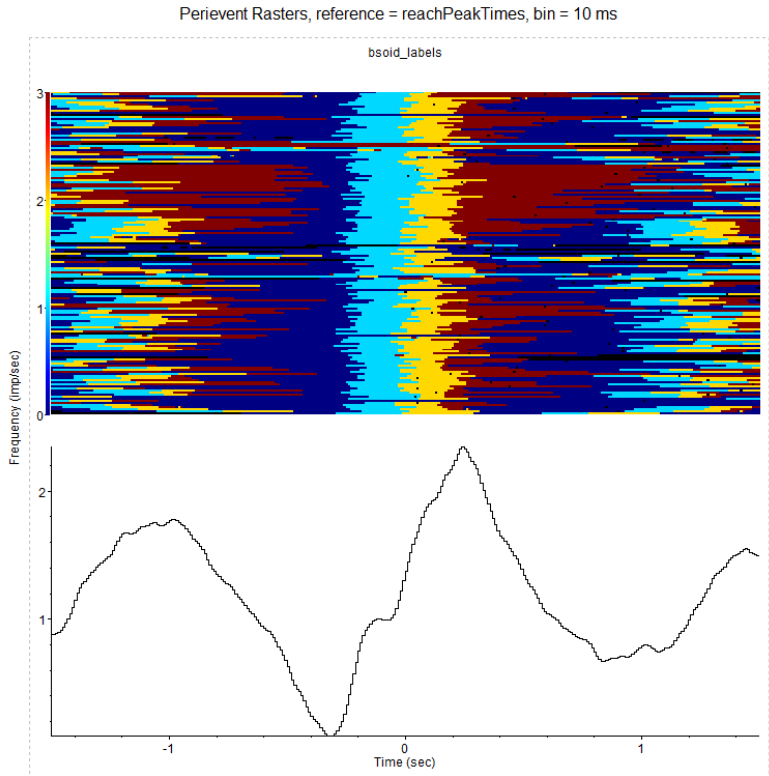
Louvain Algorithm: Resolution

- Higher resolution value leads to more communities
- Identify cycles of length 3 at minimum
- Vary resolution and calculate strength of cycles by summation of edge weights (transition probability)
- Use classification with highest summation

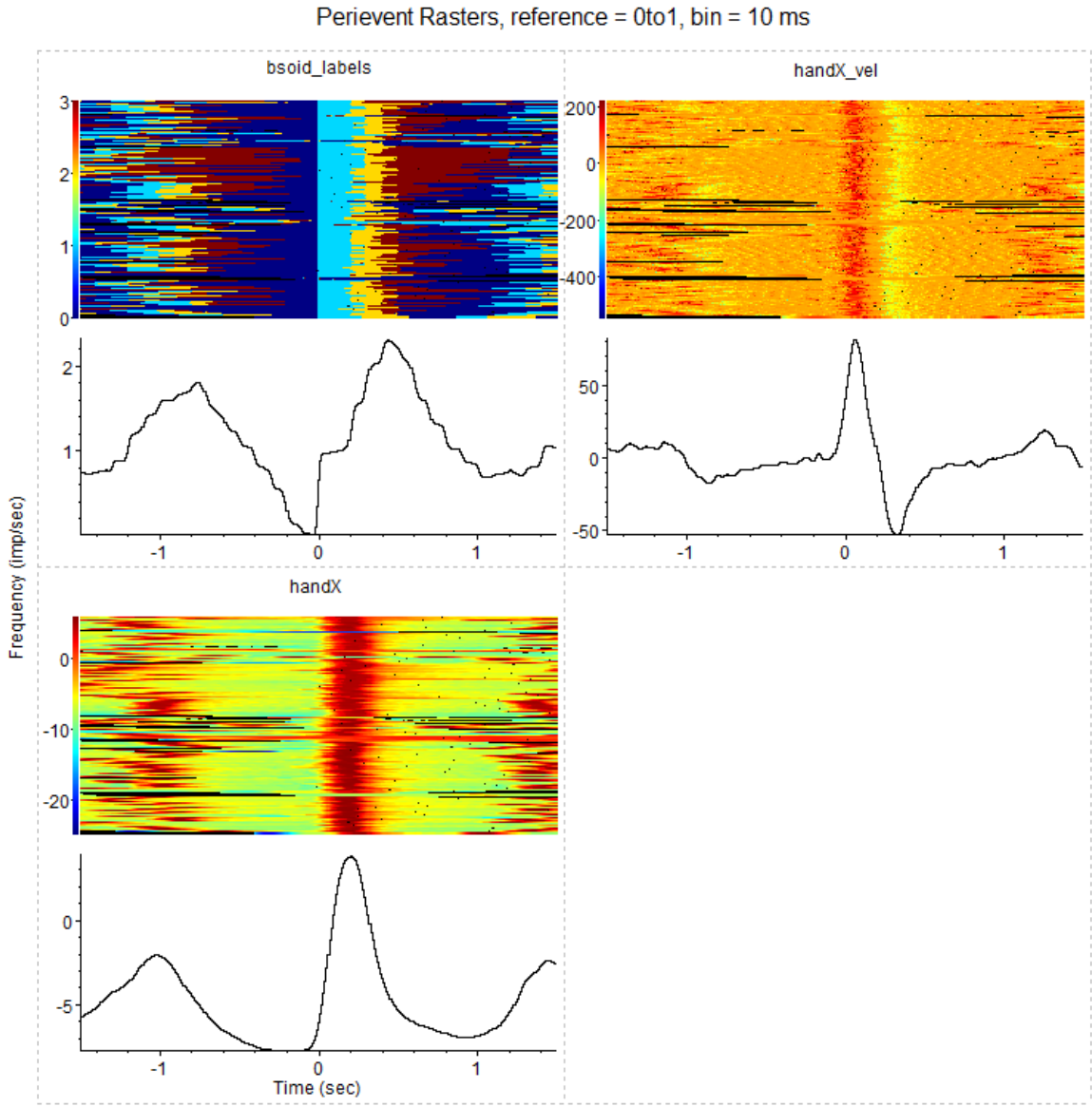
$$max_j(\sum_{E_i \in C_j} E_i)$$

Result of Cycle Strength Calculation





Reaching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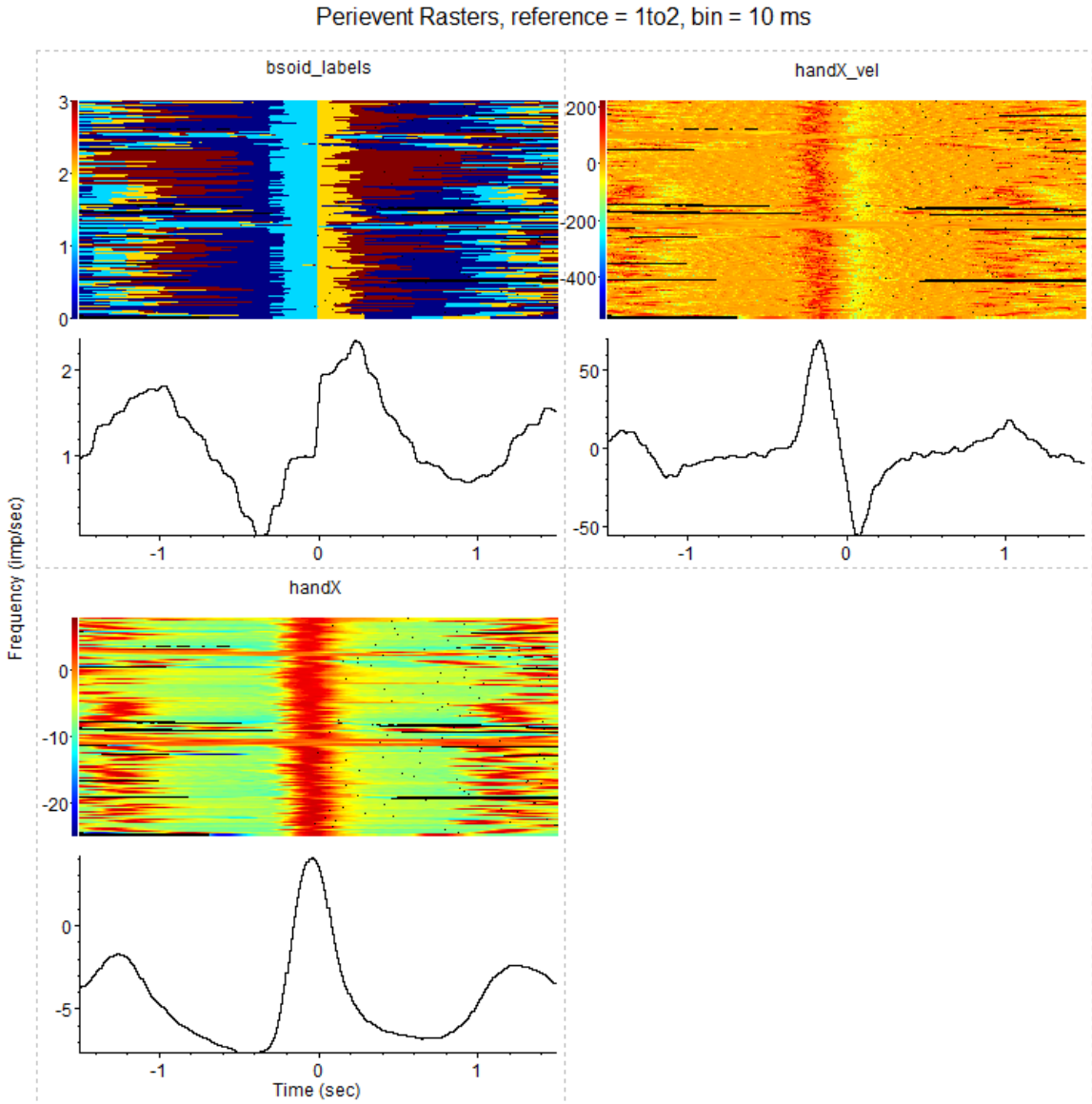
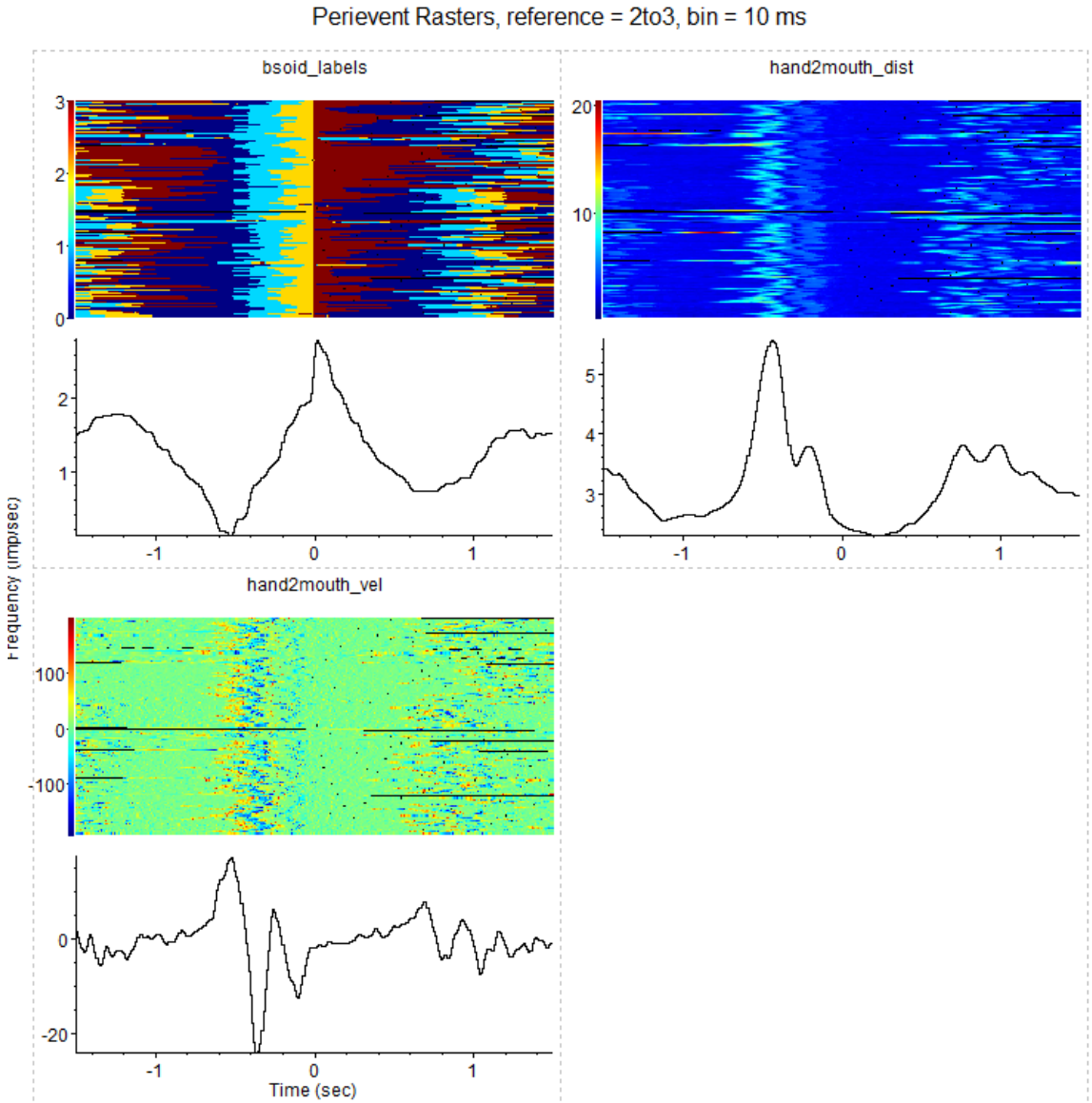
bsoid_labels
handX_vel
handX
Frequency (imp/sec)
Time (sec)

Retracting


Perievent Rasters, reference = 1to2, bin = 10 ms
bsoid_labels
handX_vel
handX
Frequency (imp/sec)
Time (sec)

Drinking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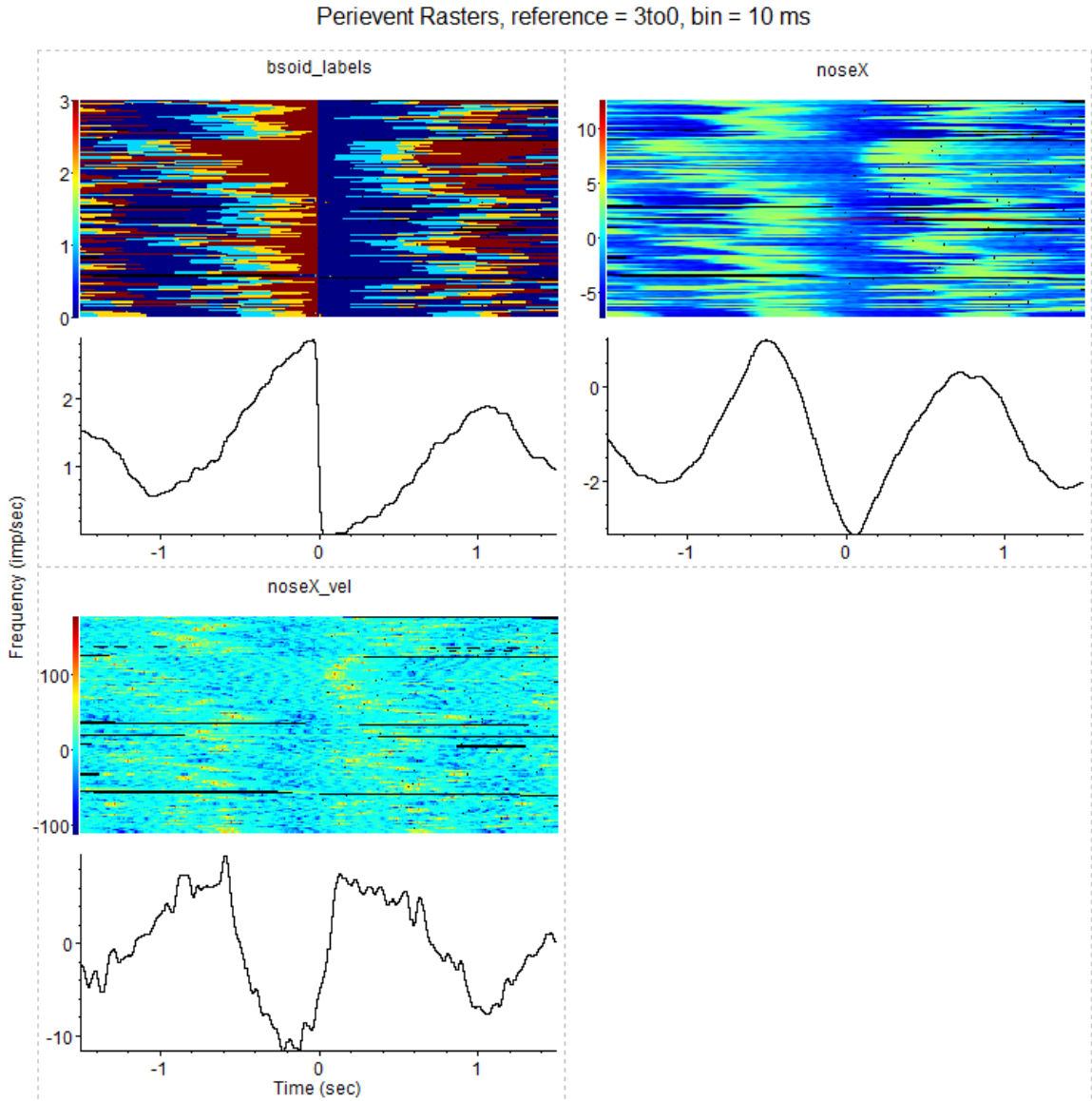
bsoid_labels
hand2mouth_dist
hand2mouth_vel
Frequency (imp/sec)
Time (sec)

Aiming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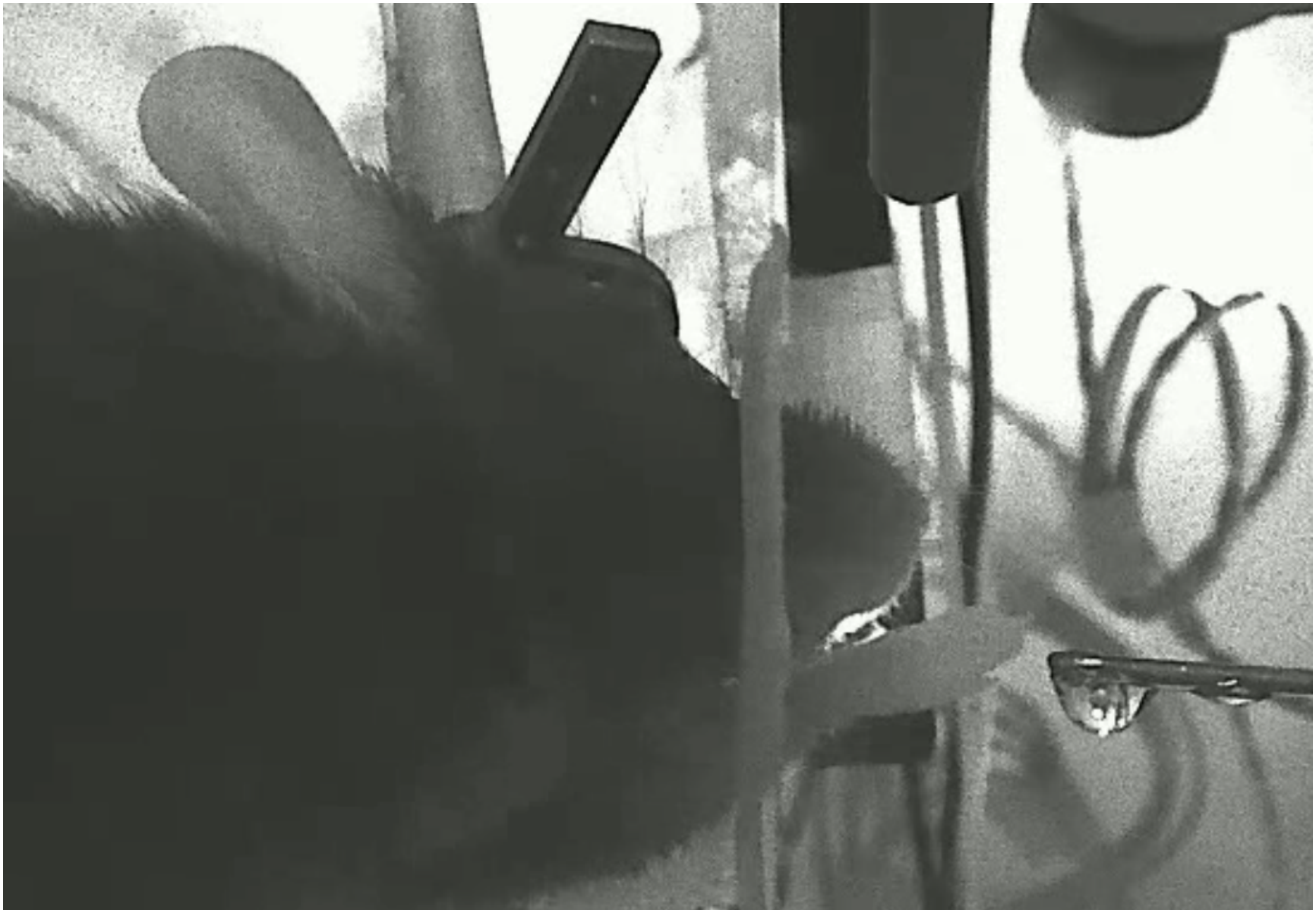
bsoid_labels
noseX
noseX_vel
Frequency (imp/sec)
Time (sec)

Video Labeled with Groups Following Clustering



Conclusion

- Louvain algorithm and cyclic strength combines sub-behaviors from B-SOiD into interpretable behaviors: aim, reach, retrieve, drink
- Drinking and aiming could be more clearly distinguished
- Few miliseconds of delay in clustering and actual behavioral change
- Add kinematic variables as attribute of vertices to further classify behaviors
- Explore clustering algorithms

Citations

- https://hdbscan.readthedocs.io/en/latest/how_hdbscan_works.html
- https://www.nature.com/articles/s41598-019-41695-z#Sec4
- https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0187276
- https://www.nature.com/articles/s41467-021-25420-x