# Inferring Social Structure of Animal Groups from Tracking Data

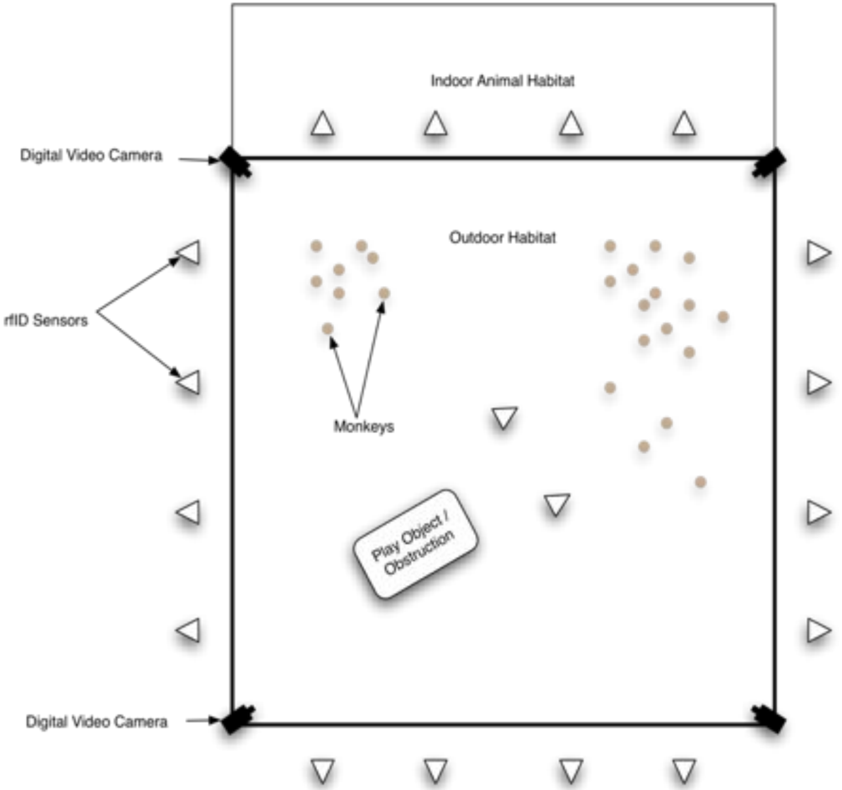
# Studying primate social structure

Social structure in primates has important implications for

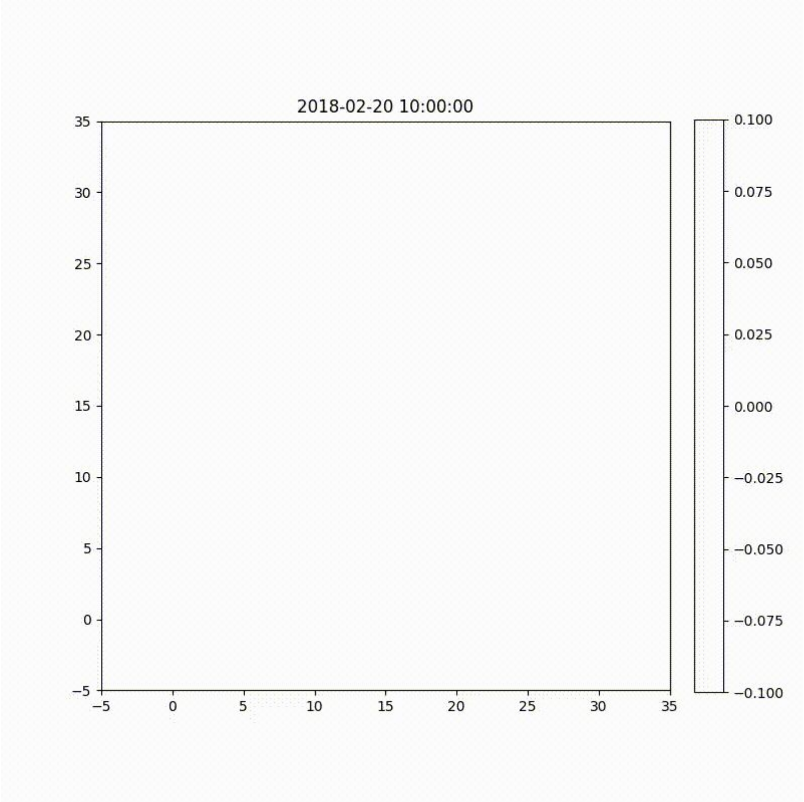
- Individual health
- Colony health
- Behavior
- Development

# Tracking System


- Collars with active RFID produce “chirps”
- Perimeter sensors compute position
- Connected camera allows for real time monitoring or logging



# Dense continuous tracking




# Automated vs Manual assessment

Manual

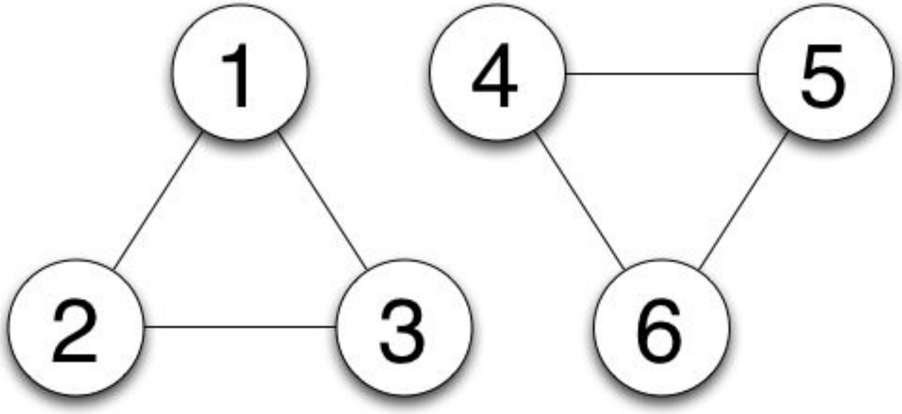
- Sparse
  - 1-2 hour observation periods
- Semantic meaning
  - “Individual A approached individual B for grooming”
- Difficult to track more than one individual at a time

Automated

- Dense
  - 4 updates per second, continuously
- Metric information
  - “Individual A approached within 0.25m of individual B
- Easy to track multiple individuals simultaneously

How can we **automatically** infer interesting properties of the group from tracking data?

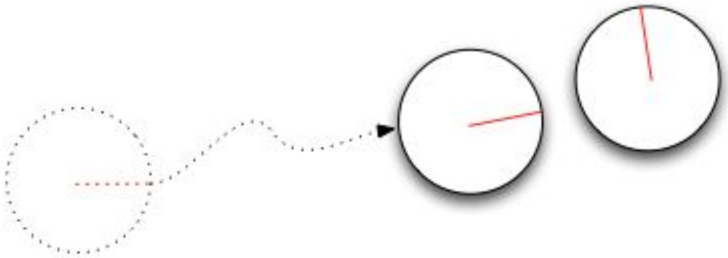
# Association preference




Who associates with whom?

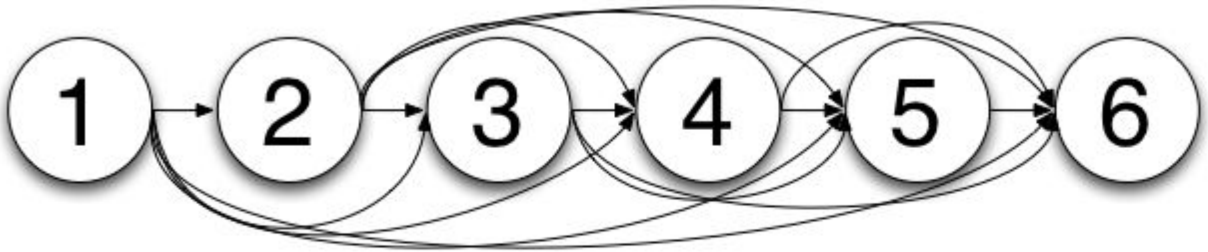
- Which individuals spend the most time together
- Identify subgroups or *cliques*
- Representation: undirected graph

# Grouping behavior



Approach at a moderate to low speed within arms reach (0.25m) and stop

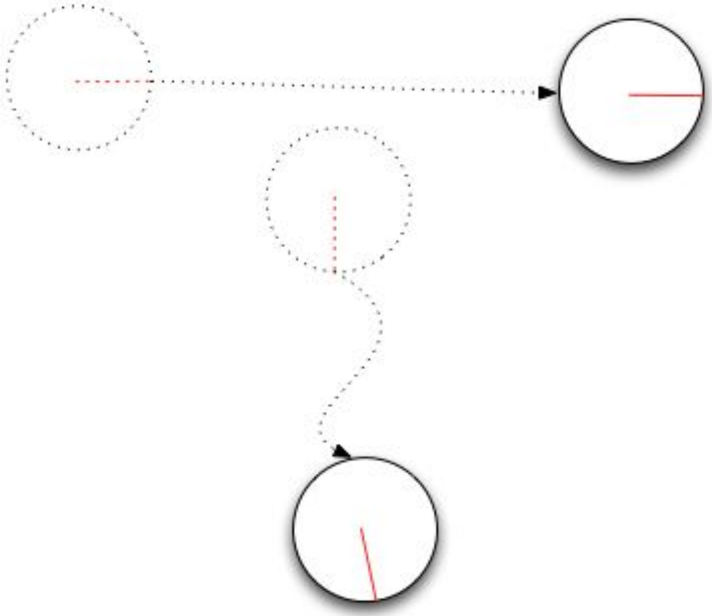
# Dominance ranks




Who defers to whom?

- Which individuals have preferential access to resources
- Group stability/instability, genetic relationships, health
- Representation: directed graph

# Avoidance behavior

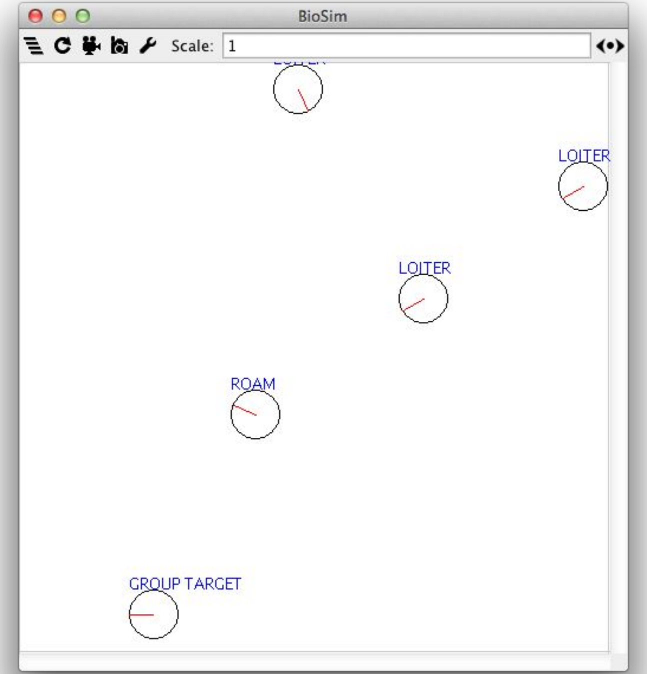


Move away from higher ranking individual, either stationary or moving at moderate to high speed

# Agent based model

Use ABM to model a small group of rhesus macaques

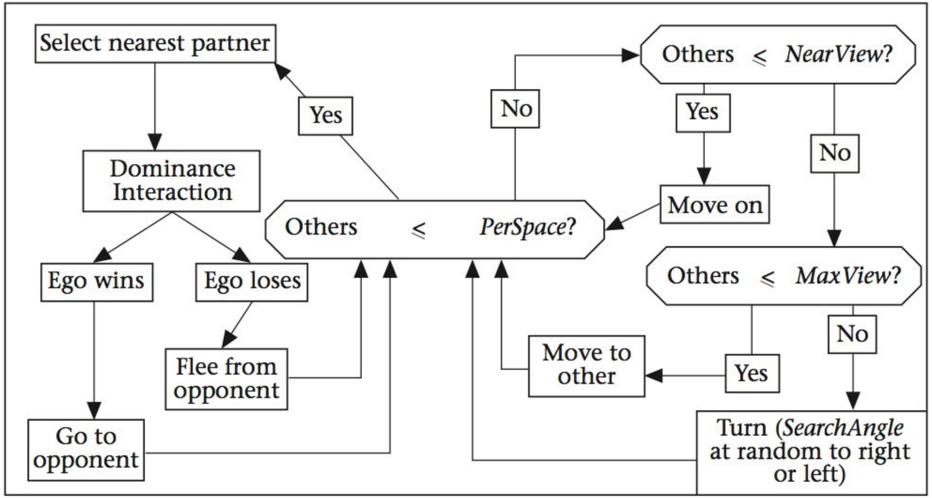
- Association (grouping) and dominance (chasing, fleeing) behaviors
- Explicit representation of social structures (association preference matrix, dominance weights)
- Data qualitatively similar to tracking data (spatial data, no orientation)



# DomWorld

DomWorld model introduced by Hemelrijk in 2000

- Dominance behaviors in group living animals
- Large groups (30+) in unbounded environments
- Dominance interactions are deterministic
- No association preference

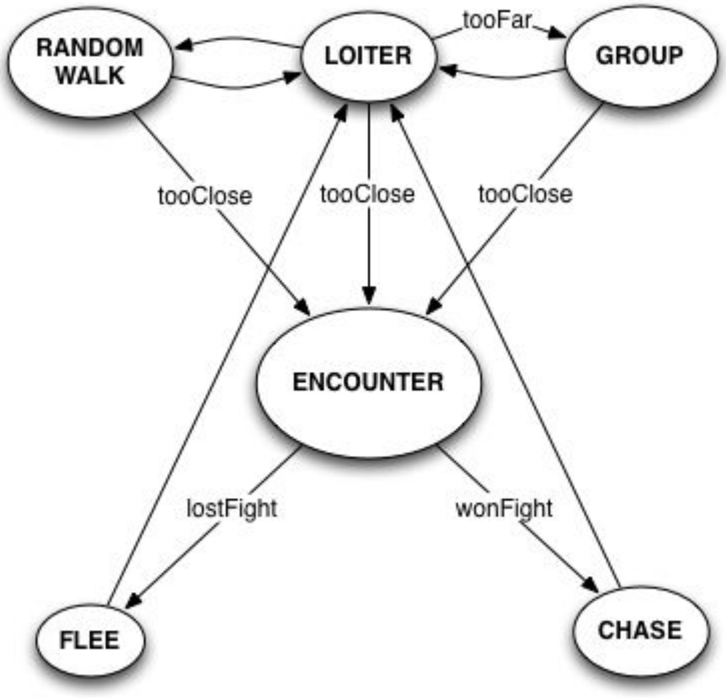



Hemelrijk, Charlotte K. (2000) “Towards integration of social dominance and spatial structure”

# SmallDomWorld

Variation of DomWorld modified for smaller groups living in enclosures

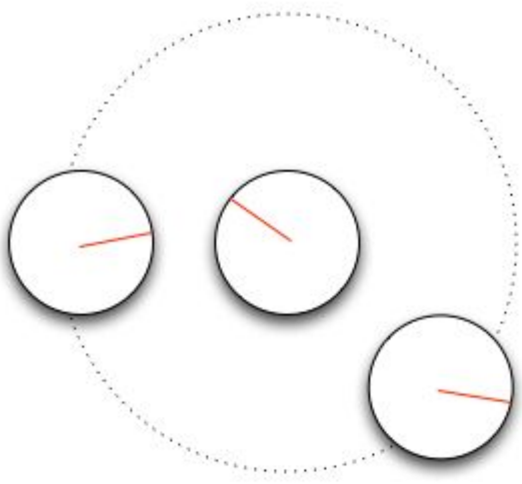
- Group size: 6 individuals
- Dominance interactions are stochastic, tunable (representation: weight)
- Individuals have association preferences (representation: matrix)



# Association behavior detection

How much time does each pair spend in proximity?

- Proximity = 0.25m, “arms reach”
- Low-speed/stationary events
- Normalized over observation period
- No orientation information

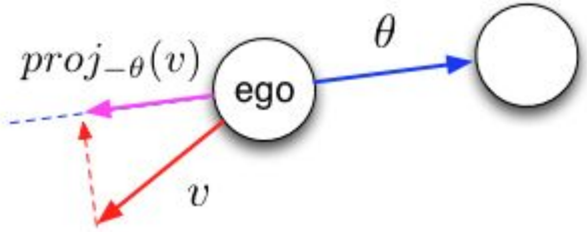


# Dominance behavior detection

Dominance relationship indicated by ratio of fleeing events

- High-speed events (low speed can be ambiguous)
- Project velocity of ego away from target 自我
- If magnitude of projection is above some threshold, ego is “fleeing” the target

If B flees from A more frequently than the reverse, there is a dominance relationship *from* A *to* B.



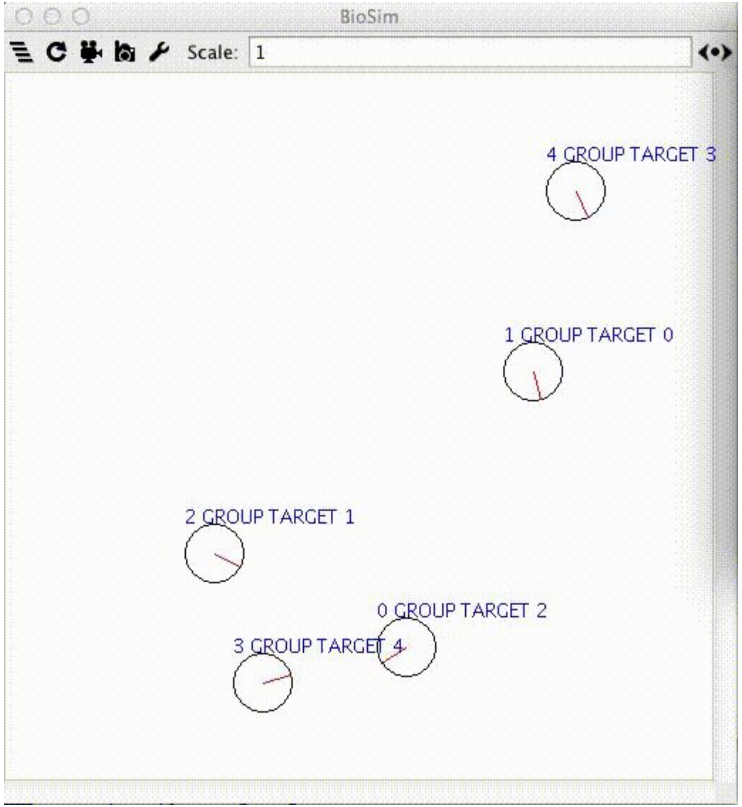

Detect fleeing events by counting the length and number of event where the magnitude of the ego's velocity projected onto the bearing(theta) between the ego and the target is larger than a threshold(f).

# Simulation

Setup

- SmallDomWorld model implemented using BioSim
- 10 runs of 24 simulated hours
- Positional data logged for each agent at 30fps
- Fixed dominance weights
- Tested three different association preference configurations

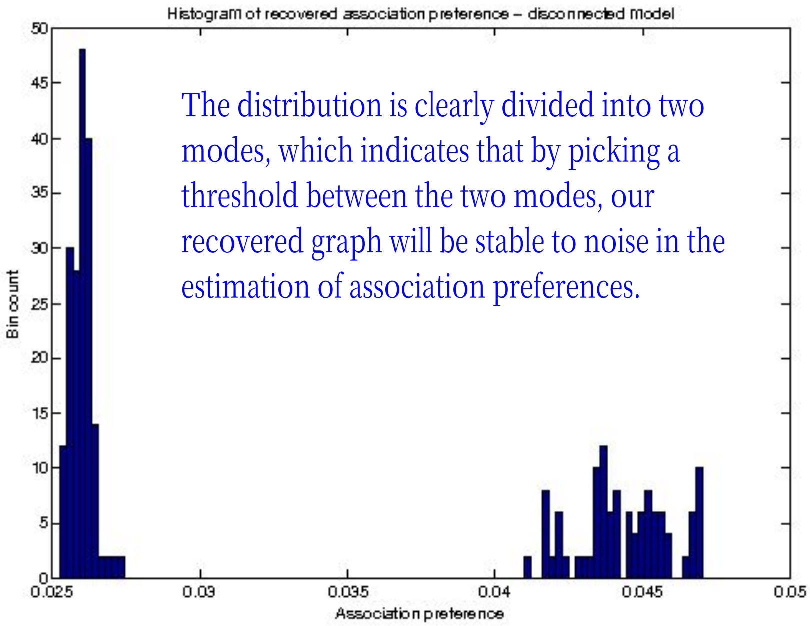
Goal: Recover dominance rankings and association preferences from logged positional data



# Choosing a threshold for association preference

In order to draw the graphs, a threshold parameter must be chosen

By examining a histogram of association preferences, we see a clear separation into two modes, indicating that choosing a threshold in between the two modes will be stable.

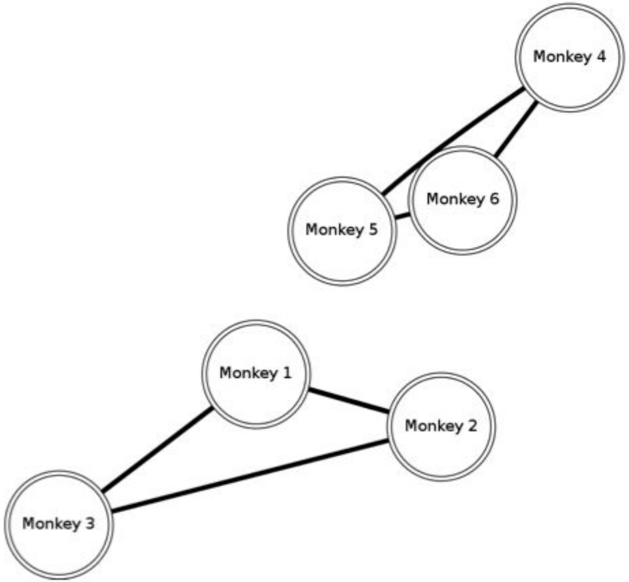


小集团、派系

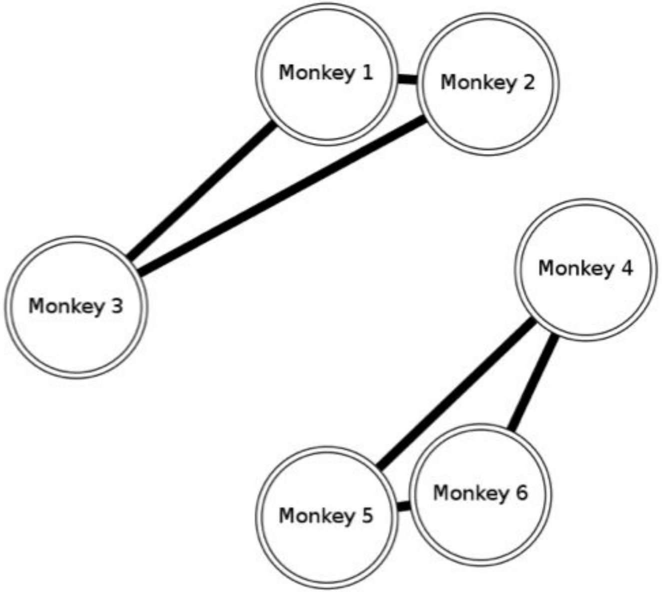
# Mutually exclusive cliques

| Monkey ID | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 1 | --- | 1 | 1 | 0 | 0 | 0 |
| 2 | 1 | --- | 1 | 0 | 0 | 0 |
| 3 | 1 | 1 | --- | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | --- | 1 | 1 |
| 5 | 0 | 0 | 0 | 1 | --- | 1 |
| 6 | 0 | 0 | 0 | 1 | 1 | --- |

# Mutually exclusive cliques recovered preferences




(a) Recovered association preference.




(b) Ground truth association preference.

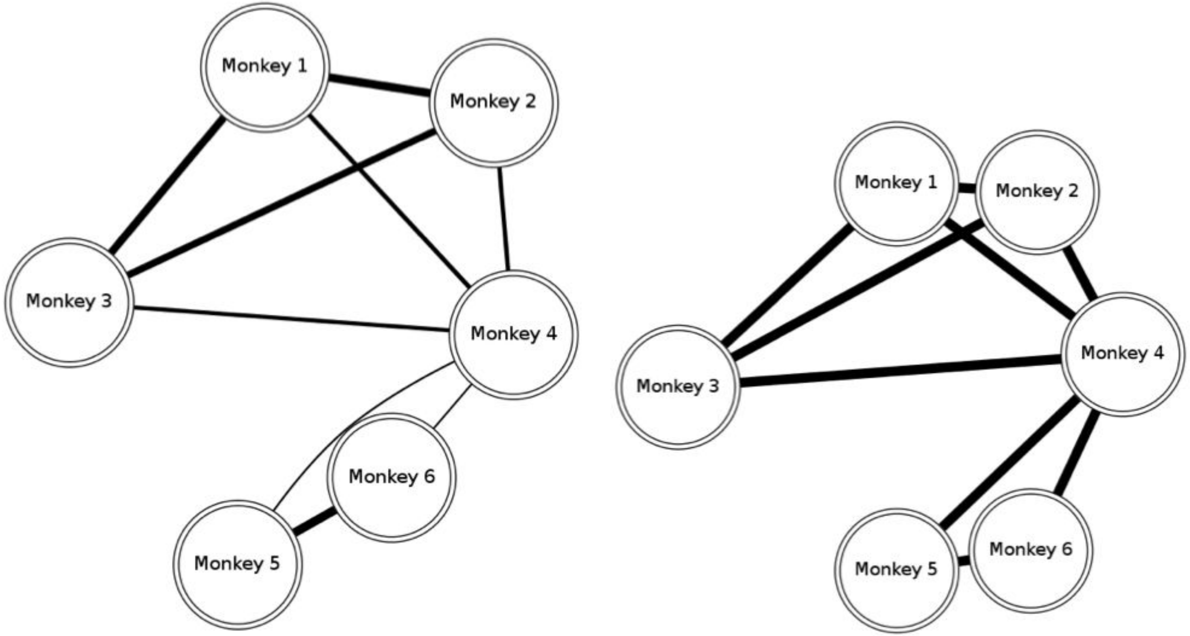
Figure 5: Association preferences for the disconnected scenario. The recovered graph (5a) closely matches the actual association preferences used in the simulation (5b). Line thickness corresponds to strength of association preference. Association preferences that fall below the threshold $\tau$ (from Equation 3) are not shown.

# Transitive hinge

| Monkey ID | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 1 | --- | 1 | 1 | 0 | 0 | 0 |
| 2 | 1 | --- | 1 | 0 | 0 | 0 |
| 3 | 1 | 1 | --- | 0 | 0 | 0 |
| 4 | 1 | 1 | 1 | --- | 1 | 1 |
| 5 | 0 | 0 | 0 | 0 | --- | 1 |
| 6 | 0 | 0 | 0 | 0 | 1 | --- |

Transitive preference: If A prefers to associate with B, and B with C, A prefers C as well.

# Transitive hinge recovered preferences




(a) Recovered association preference.

(b) Ground truth association preference.

Figure 8: Association preferences with hinge node. The recovered graph (8a) closely matches the actual association preferences used in the simulation (8b). Line thickness corresponds to strength of association preference. Association preferences that fall below the threshold $\tau$ are not shown.

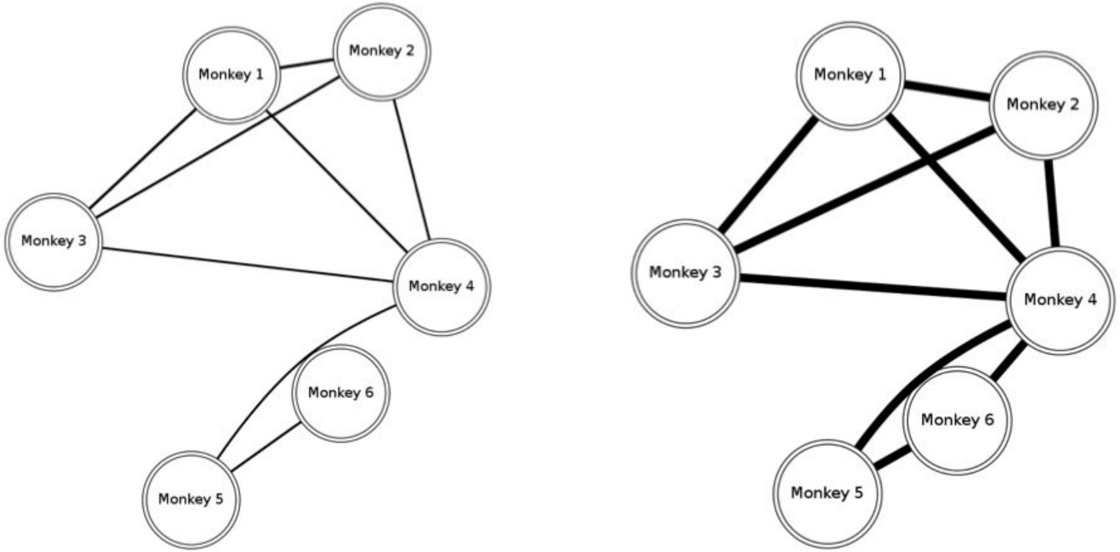
# Non-transitive hinge

| Monkey ID | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 1 | --- | 1 | 1 | 1 | 0 | 0 |
| 2 | 1 | --- | 1 | 1 | 0 | 0 |
| 3 | 1 | 1 | --- | 1 | 0 | 0 |
| 4 | 1 | 1 | 1 | --- | 1 | 1 |
| 5 | 0 | 0 | 0 | 1 | --- | 1 |
| 6 | 0 | 0 | 0 | 1 | 1 | --- |

Both cliques associate with 4, but not with each other

eg: 4喜欢56，而123喜欢4，按理说123也应该喜欢56，但并不是如此，所以是non-transitive. 这种social structure容易判断出错

# Non-transitive hinge recovered preferences




(a) Recovered association preference.

(b) Ground truth association preference.

Figure 9: Association preferences for the hinge node scenario using non-transitive preferences. The recovered graph (9a) is missing a link between monkey 6 and monkey 4 in the actual association preference graph (9b). Notice also that the magnitude of the preferences — shown by the thickness of the edges — is much closer to the threshold value $\tau$. Picking smaller $\tau$ results in additional edges that are not present in the simulated behavior. The non-transitive preferences make it difficult to choose a stable $\tau$.

# Quantitative results

We see a statistically significant ability to recover the correct association preference parameters in all but the non-transitive scenario.

Table 2: Frobenious error of recovered association preference as compared to a randomly generated symmetric, normalized matrix with zero diagonal. Averaged over 10 runs.

| Recovered AP | Avg. error (std.) | random AP |
|---|---|---|
| disconnected | 0.1744 (0.0014) | 0.2408 (0.0326) |
| neutral hinge | 0.1002 (0.0015) | 0.1797 (0.0350) |
| preferred hinge | 0.1388 (0.0004) | 0.1869 (0.0158) |

# Live animals - tracking data

- Tracking data: 30 days @ 30fps
- Tracking covered outdoor enclosure (indoor area not covered)
- Node diameter: length of observation time
- Link threshold: mean association preference
- Link width: strength of preference

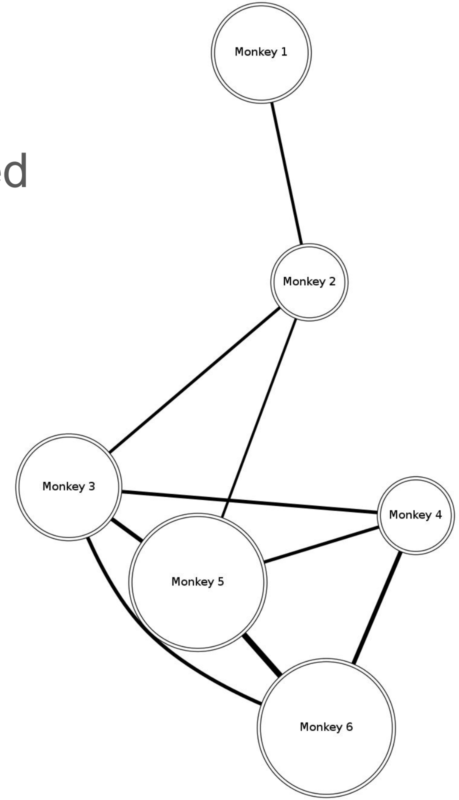
# Live animals - recovered social structures

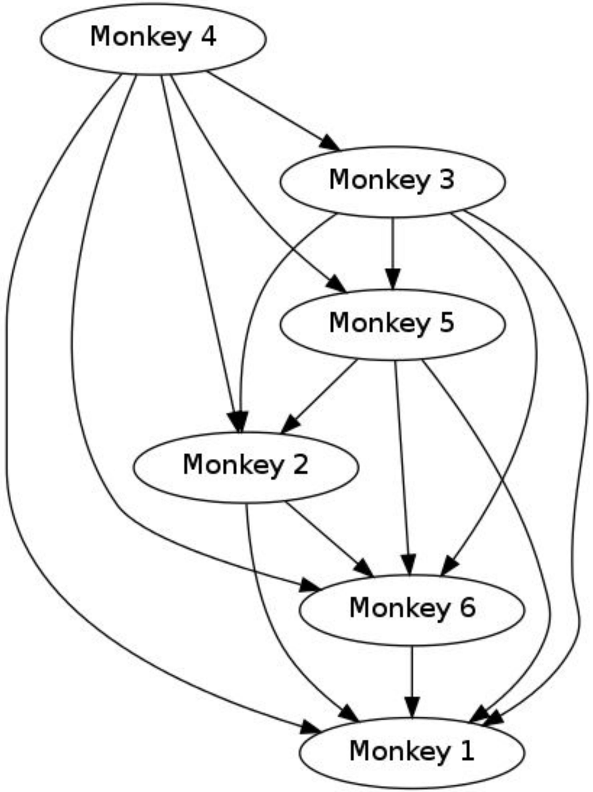
Dominance hierarchy:

- Matches hierarchy determined by human expert
- Linear and stable

Association preference:

- No ground truth
- {3,4,5,6} clique matches with observation



# Conclusion

Presented here

- Methods for inferring social relationships from dense spatial data.
- ABM framework for evaluating these methods

Other work

- Coordinating video and spatial tracking
- Automatically detecting anomalies
- Recognition of specific behaviors of interest