Birds Behaviour Analysis from Bounding-Box Annotations at a Feeder

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Abstract

Understanding how animals interact around shared resources is a central question in behavioural ecology and computational ethology. In this report, I present a simple but informative analysis of multi-species bird behaviour at a feeder using only bounding-box annotations in COCO format. Without using pose estimation or identity tracking, I quantify (i) species co-occurrence patterns, (ii) social spacing between individuals, (iii) spatial occupancy of the feeder area, (iv) a species-level co-feeding social network, and (v) a centrality-based proxy for dominance at the feeder. These metrics together provide a first view of social structure, tolerance, and resource access in a mixed-species bird community, and illustrate how meaningful behavioural information can be extracted from standard object-detection annotations.

1 Introduction

Mixed-species bird flocks and feeding aggregations provide natural examples of social interactions and competition over limited resources. Traditionally, studying these behaviours requires manual field observation or detailed pose and trajectory tracking. However, many modern datasets contain only bounding-box annotations produced for object detection. The question I address here is:

> *What kind of social and behavioural information can we recover from feeder images that only have species labels and bounding boxes?*

This report describes a small computational ethology pipeline built on top of such a dataset. The images show several bird species visiting a feeder; each individual is annotated with a bounding box and a species label in COCO format. From these annotations alone, I derive a series of group-level and species-level behavioural metrics:

- co-occurrence patterns: which species feed together,
- social spacing: how close individuals of different species stay to one another,
- spatial occupancy: where each species tends to position itself at the feeder,
- a co-feeding social network between species,
- and a dominance proxy based on spatial centrality in crowded scenes.

The goal is not to build the most complex model, but to demonstrate that even simple geometric computations on bounding boxes can reveal interpretable structure in animal behaviour.

2 Dataset and Annotations

2.1 Data format

The data are stored in COCO format, with:

- a list of `images`, each with a unique `id` and `file_name`,
- a list of `annotations`, where each entry has an `image_id`, a `category_id`, and a bounding box `[x, y, width, height]`,
- a list of `categories`, mapping `category_id` to a species name.

The relevant categories correspond to bird species such as `Common_Myna`, `House_Crow`, `Male_Rose_Ringed_Par` etc. A generic class like `objects` is ignored in the analysis.

2.2 Basic preprocessing

In Python, I load the COCO JSON file and construct:

- a dictionary from `category_id` to species name,
- a mapping from `image_id` to a list of all its annotations.

This allows iterating over images and accessing all birds that appear in each frame.

For each annotation, the bounding box is interpreted as

$$[x, y, w, h]$$

where (x, y) is the top-left corner and (w, h) are the width and height in pixels. The centroid of the bird is then

$$c_x = x + \frac{w}{2}, \quad c_y = y + \frac{h}{2}.$$

Using `PIL`, I load each image to obtain its width W and height H so the centroid can also be expressed in normalized coordinates:

$$\tilde{x} = \frac{c_x}{W}, \quad \tilde{y} = \frac{c_y}{H}.$$

3 Methods

In this section, I describe the five main metrics computed from the annotations.

3.1 Species co-occurrence

For each image, I collect the set of species that appear in that frame. If species s_1 and s_2 both appear in the same image, I increment a co-occurrence counter for the ordered pair (s_1, s_2). Formally, let $S(I)$ be the set of species present in image I; then

$$\text{cooccurrence}(s_1, s_2) \mathrel{+}= \begin{cases} 1 & \text{if } s_1 \in S(I) \text{ and } s_2 \in S(I), s_1 \neq s_2, \\ 0 & \text{otherwise.} \end{cases}$$

Stacking these counts into a matrix over all species gives a co-occurrence matrix. I visualize this as a heatmap, where brighter values indicate species pairs that frequently feed together.

3.2 Social spacing: pairwise distances

Within each image, I compute the centroid for every bird and store the corresponding species label. For a frame with N birds, I build an $N \times N$ distance matrix D using Euclidean distance in normalized coordinates:

$$D_{ij} = \|\mathbf{c}_i - \mathbf{c}_j\|_2 \,,$$

where $\mathbf{c}_i = (\tilde{x}_i, \tilde{y}_i)$ is the normalized centroid of bird i.

For each unordered pair of birds (i, j) with species (s_i, s_j), the distance D_{ij} is appended to a list associated with the species pair (s_i, s_j). Over the entire dataset, this yields a distribution of distances for every species pair. These distributions are summarized using a boxplot, which can reveal:

- which species tend to feed close together,
- which pairs maintain larger distances,
- whether conspecifics (same-species pairs) cluster differently than heterospecific pairs.

3.3 Spatial occupancy of the feeder

To understand how each species uses space around the feeder, I aggregate the normalized centroid positions $(\tilde{x}, \tilde{y})$ for each species separately. For species s, let

$$\mathcal{C}_s = \{(\tilde{x}_k, \tilde{y}_k) \mid \text{bird } k \text{ has species } s\}.$$

I then plot a 2D histogram (heatmap) over the normalized image plane. Areas with high density indicate preferred positions of that species (e.g., closer to the food tray, on a particular side of the feeder, or on surrounding branches).

This method does not require any temporal information and directly reveals spatial preferences and potential resource partitioning between species.

3.4 Co-feeding social network

The co-occurrence analysis can also be represented as a graph. I build an undirected weighted graph G where:

- each node is a species,
- an edge (s_1, s_2) exists if the two species ever co-feed,
- the edge weight is the total number of frames in which both species appear together.

The graph is visualized using a spring layout, where edge thickness is proportional to the co-occurrence weight. This representation highlights:

- tightly connected groups of species that frequently share the feeder,
- more isolated species that rarely co-feed with others,
- potential "bridge" species that connect otherwise separated groups.

3.5 Dominance / centrality score

Dominance at a feeder often manifests as more dominant species occupying central, high-value positions, while subordinate species are pushed to the periphery. To approximate this from static images, I define a *centrality-based dominance proxy*.

For each image with at least $N \geq 3$ birds:

1. Compute the centroid of all birds in normalized coordinates:

$$\mathbf{c}_{\text{group}} = \frac{1}{N} \sum_{i=1}^{N} \mathbf{c}_i.$$

2. For each bird i, compute its distance to this group centroid:

$$d_i = \|\mathbf{c}_i - \mathbf{c}_{\text{group}}\|_2 .$$

3. Let s_i be the species of bird i. For each species, accumulate a weighted sum of distances:

$$\text{sum}_s \mathrel{+}= d_i \cdot N, \quad \text{weight}_s \mathrel{+}= N.$$

The factor N gives more importance to crowded scenes, where competition for space is stronger.

After processing all images, the mean distance to the group centroid for species s is:

$$\bar{d}_s = \frac{\text{sum}_s}{\text{weight}_s}.$$

To convert this into a dominance score where higher values correspond to more central (and thus more dominant) species, I rescale:

$$\text{dominance}_s = 1 - \frac{\bar{d}_s - d_{\min}}{d_{\max} - d_{\min}},$$

where $d_{\min}$ and $d_{\max}$ are the minimum and maximum mean distances across species. This yields scores in $[0, 1]$, which are plotted as a bar chart sorted from highest to lowest dominance.

4 Implementation Overview

The analysis is implemented in Python using common scientific libraries:

- `json` and `os` for file handling,
- `numpy` and `pandas` for numerical computations and tabular data,
- `PIL` for loading image dimensions,
- `scipy.spatial.distance.cdist` for pairwise distance computation,
- `matplotlib` for plotting,
- `networkx` for social network construction and visualization.

The script produces the following output files in a `results/` directory:

- `cooccurrence_heatmap.png`
- `social_spacing_boxplot.png`
- `occupancy_<species>.png` for each species
- `social_network_graph.png`
- `dominance_barplot.png`

Each of these can be directly included as figures in this report.

5 Results

In this section you can include and describe the plots generated by the script. Example figure environments are shown below; replace the filenames with your actual results and add text describing what you observe.

5.1 Co-occurrence and social spacing

5.2 Spatial occupancy

5.3 Social network and dominance

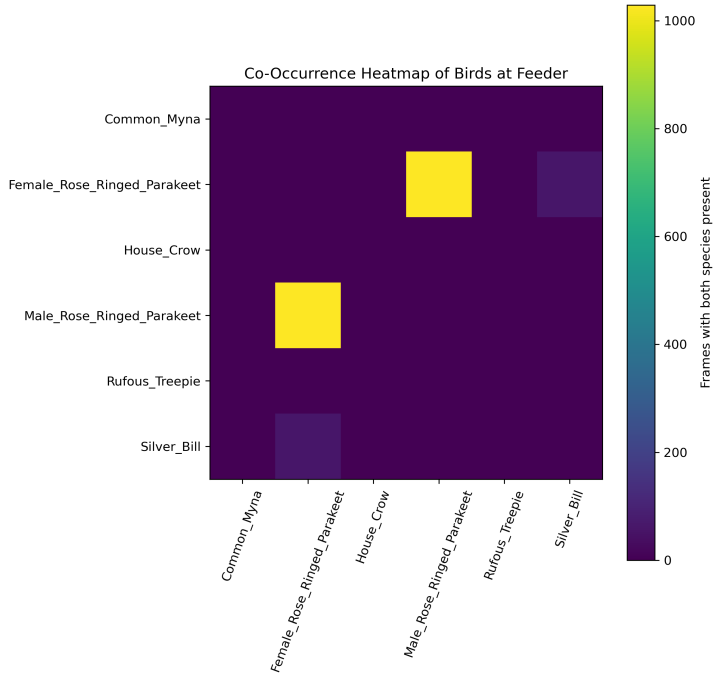


Figure 1: Co-occurrence heatmap of bird species at the feeder. Each cell shows how many frames contain a particular pair of species together.

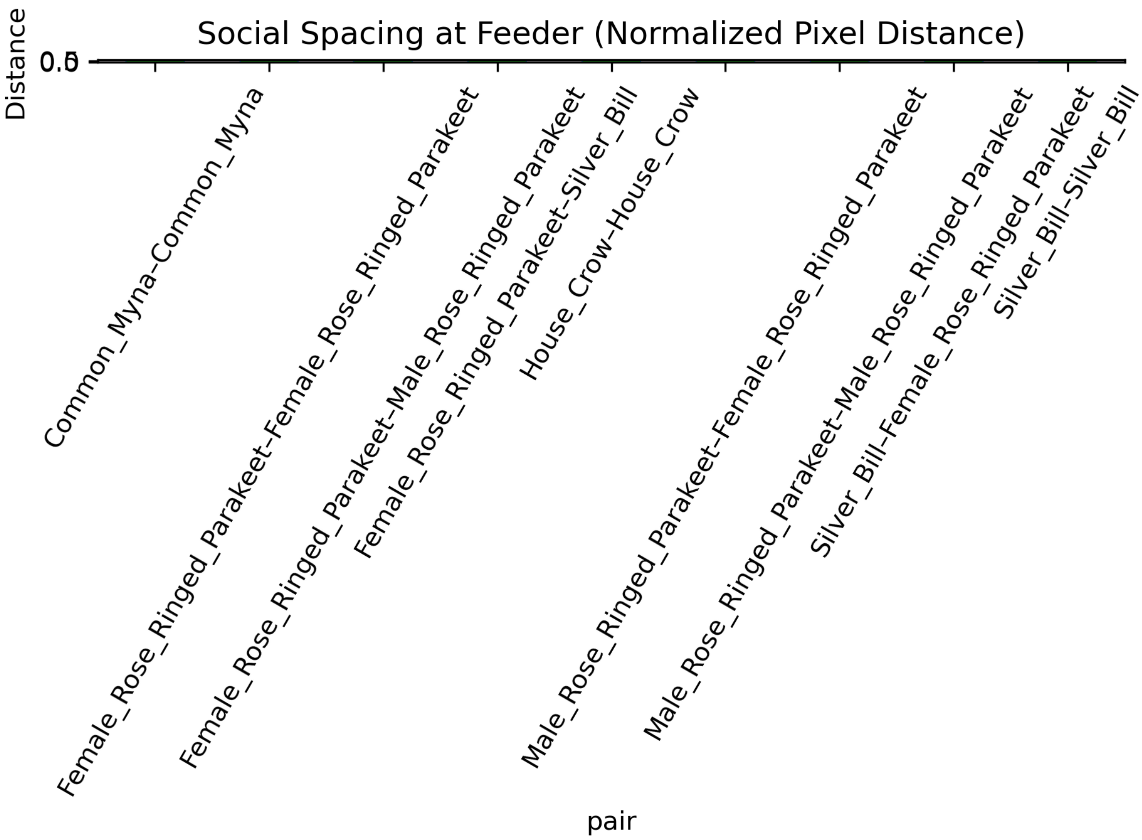
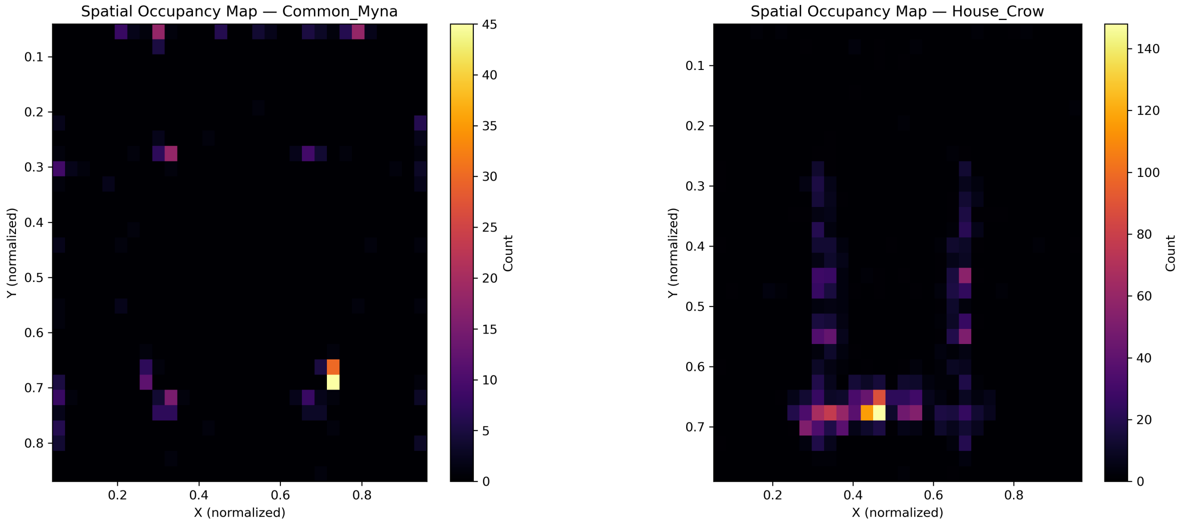


Figure 2: Distribution of pairwise distances between species pairs, showing social spacing patterns among birds at the feeder.



(a) Common Myna

(b) House Crow

Figure 3: Spatial occupancy maps (example species). Brighter areas indicate locations where that species is observed more frequently.

Figure 4: Species co-feeding social network. Nodes are species; edge thickness reflects how often species feed together.

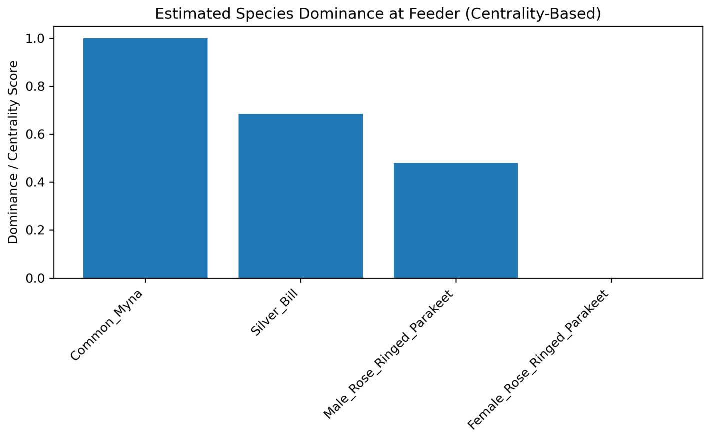


Figure 5: Centrality-based dominance scores for each species. Higher scores indicate species that tend to occupy more central positions in crowded scenes.

6 Discussion

Even though the dataset only contains bounding-box annotations without pose or identity tracking, the analysis reveals several aspects of social behaviour at the feeder:

- **Species associations:** The co-occurrence heatmap and social network graph highlight which species regularly share the feeder and which appear more independently. Strong edges in the graph indicate tolerant or at least co-feeding species.
- **Social spacing:** The distance distributions show how comfortable different species pairs are with close proximity. Smaller median distances suggest higher tolerance or flocking, while larger distances may reflect avoidance or aggression.
- **Spatial preferences:** Occupancy maps show whether certain species prefer central positions (near the food source) or peripheral locations (e.g., waiting areas, branches). This can relate to both foraging strategy and risk avoidance.
- **Dominance structure:** The centrality-based dominance score provides a first approximation of which species tend to occupy valuable central positions in crowded scenes. Although this is an indirect measure, it is consistent with the idea that dominant individuals or species maintain access to the core of the resource.

These results demonstrate that even without detailed pose tracking, it is possible to extract meaningful behavioural signals from object detection annotations.

7 Limitations and Future Work

There are several limitations to this approach:

- **No identity tracking:** The same individual bird may appear multiple times, but is treated as an anonymous member of its species. Individual-level dominance or personality cannot be inferred.
- **Static snapshots:** Temporal dynamics are not fully exploited. Each image is treated independently, even if images come from a continuous video.
- **Indirect dominance proxy:** Centrality at the feeder is only one component of dominance and may be influenced by other factors (e.g., feeder geometry or camera angle).

Future work could address these limitations by:

- adding multi-object tracking to build trajectories and estimate individual-level metrics,
- integrating pose estimation (e.g., DeepLabCut) to capture posture and more subtle behaviour (e.g., threat displays, vigilance),
- modeling temporal sequences of frames to study approaches, displacements, and avoidance behaviour over time,
- extending the analysis to different environmental conditions or feeder setups to test how social structure changes.

8 Conclusion

This report shows that meaningful social and spatial structure can be recovered from a relatively simple dataset of feeder images annotated with bounding boxes and species labels. By combining co-occurrence analysis, social spacing metrics, spatial occupancy maps, a co-feeding network, and a dominance proxy, it is possible to characterize aspects of tolerance, competition, and resource access in a mixed-species bird community.

More broadly, this work illustrates how standard computer vision annotations can be repurposed for behavioural analysis, providing a bridge between object detection and computational ethology.