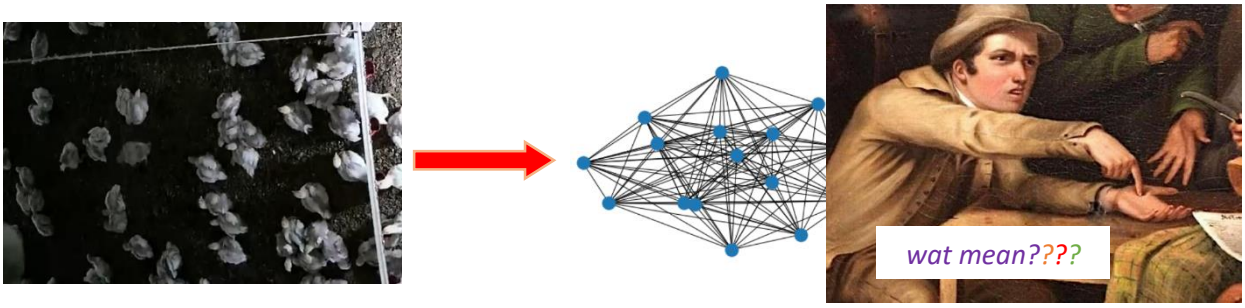
Network analysis outline

Using the distances between birds as a starting point (derived from upstream bird detection task), the potential solution envisioned and outlined here involves summarizing snapshots taken from a video feed into easily interpretable summary statistics derived from analysis using graph representations. The aim is to create a proxy for animal welfare/environmental suitability. Other possible considerations can include typical clustering techniques, statistical analysis of the distance density distributions etc.

The question to be answered here is, can we distill and quantify images into summary metrics that allow for easy comparison, interpretation and monitoring over time? Graph visualizations by themselves are not very interpretable or useful to the end user.

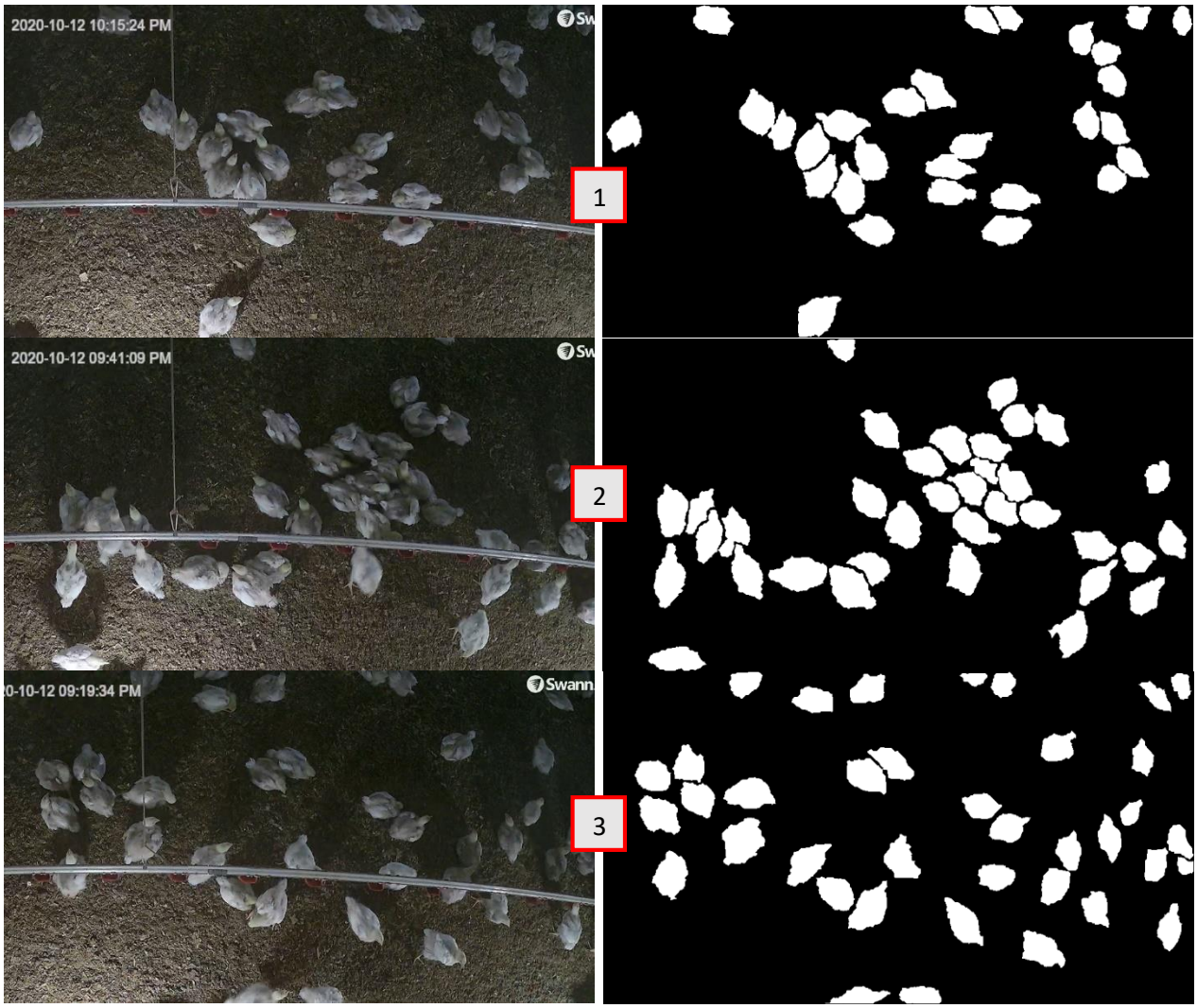


Here's how such a solution might work:

1) Every 10/30/60? minutes, grab a snapshot from a monitoring feed. If there are adjacent cameras monitoring different areas of the same flock that increases the field of vision, the data can be aggregated to increase the sample size.
2) Bird + centroid detection -> Distance calculation -> Construct graphs
3) Calculate statistics
    a. Degree
    b. Distance
    c. Modularity, communities etc.
4) Alert if
    a. a metric breaches a threshold
    b. distributions deviate significantly from normal
5) Output statistics can be used together with environmental readings (simple logic/ML models)

Method

For POC purposes, the following images and hand-drawn masks are used. The images are cropped as most of the available videos have feeders which concentrates the birds. Visually there are differences in the distribution (image 3 looks the most uniform), however the water points might introduce some biases to the birds' positions.



Base graph

The pairwise distance matrices derived from the centroids are converted to a graph format. The nodes in this case are the individual detected bird centroids. The edges of the graph are weighted by the pairwise Euclidean distances. The graph nodes here are unlabelled, meaning that there is no identity assigned to each bird.

For example, if we grab 2 snapshots 2 hours apart, and the occupied positions are identical but sometime along the way the birds have swapped positions, the 2 graphs will be considered identical as we are interested only in the overall representation of the relative distances between birds.

Summary statistics

https://i11www.iti.kit.edu/_media/projects/spp1126/files/bs-ns-05.pdf

Type of network statistics:

Single-valued vs distribution

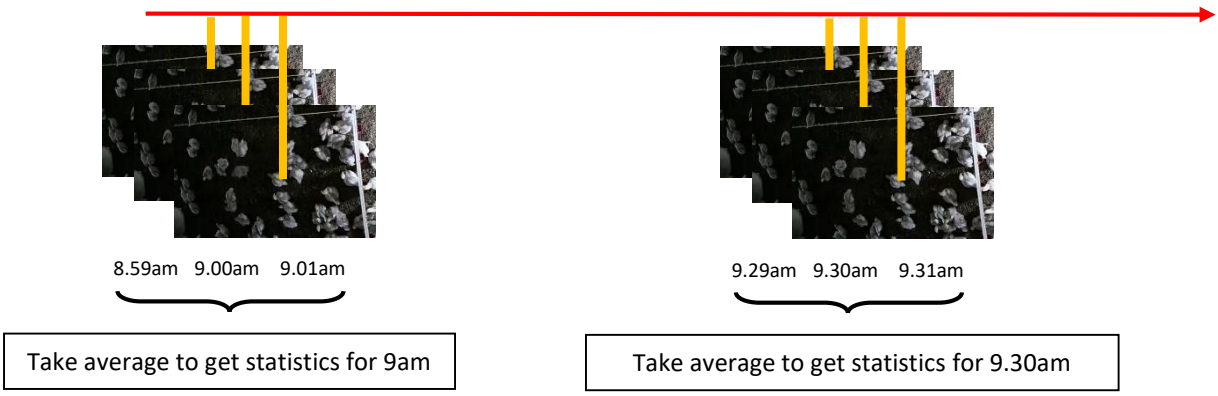
Global vs local

As it turns out, there doesn't seem to be a single-valued distance metric to calculate the similarity between 2 unlabelled networks with weighted edges and differing number of nodes. Algorithms researched so far seem to mostly work with labelled graphs. Don't think graph edit distance is applicable here.

How it's practical

Monitor for 1) Single-valued statistic exceeding threshold, 2) Deviation of overall distribution from a baseline. Need to establish what is a good baseline/threshold/normal distribution, or if there are any data for what is undesirable.

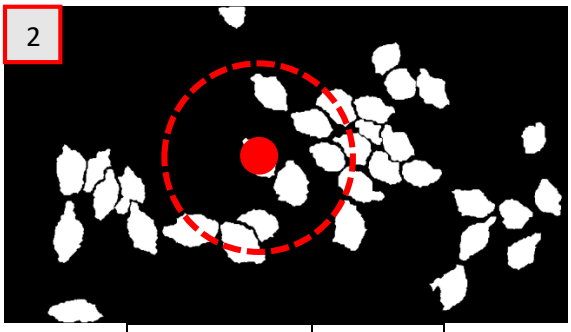
Eg: Taking snapshots every 30 min



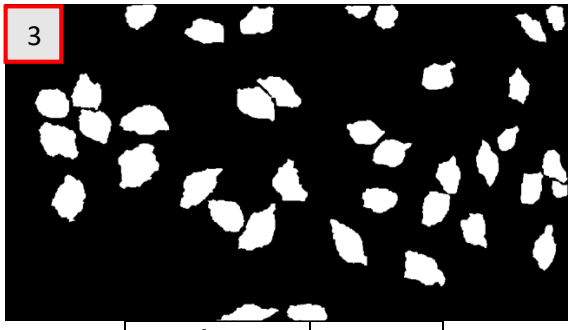
Vertex/node degree(s)

- Common, easily computed statistic
- Consider pruning edges that are above a threshold distance
- Single-valued
    - Average degree
    - Max degree?
    - X^{th} percentile degree?
- Distribution
    - Distribution of degrees for all nodes

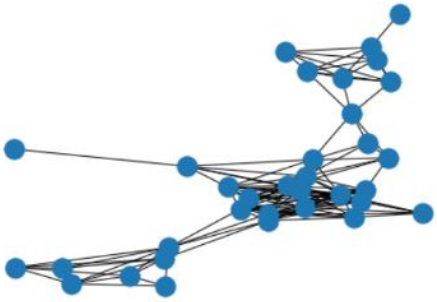
Example: Mask 2 vs Mask 3

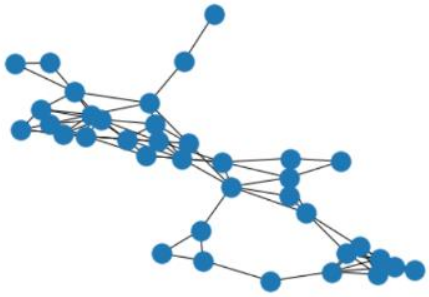


Avg deg	7.76
Max deg	14



Avg deg	5.02
Max deg	9





The red circle indicates the arbitrary radius used in this example whereby edges to any birds outside of this radius are pruned.

Distance statistics

- Prune edges with threshold, weigh close neighbours using inverse distance etc. such that a node is weighted more if 1) there are more nodes within a radius, 2) if neighbouring nodes are closer
- Lonely birds are therefore weighted 0
- Single-valued
    - Average weight of all nodes
- Distribution
    - Distribution of degrees for all nodes

Clustering coefficient (https://en.wikipedia.org/wiki/Clustering_coefficient)

- Measure tendency of nodes to cluster
- TBD on relevance (depends on network size)
- Average coefficient for whole graph or per node

Modularity
(https://networkx.org/documentation/stable/reference/algorithms/generated/networkx.algorithms.community.quality.modularity.html#networkx.algorithms.community.quality.modularity)

- Measure of strength of clusters in network (whether clusters are well-separated)
- TBD on relevance (depends on network size)

Community detection

- Count number of detected communities + community size

- Eg. Low number of detected communities – How to differentiate between a well-spaced out flock vs a few big cluster of birds

Other points

- Camera feed (or at least the area of focus) probably should not include feeders, as there will obviously be clustering that is not representative of general environmental conditions
- Problem of overlapping birds for automated labelling, especially if there is a large degree of crowding/birds are more mature and larger. CNN-based detection methods either via object detection or semantic segmentation might have difficulty separating birds as they tend to have a bias towards using the texture rather than shape for identification (https://arxiv.org/pdf/1811.12231.pdf), head detection is a good idea if the resolution is satisfactory
- Individual bird detection as the upstream task is primary determinant of downstream efficacy