Evaluation of shepherding algorithms based on flock properties

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Collective behaviour course research seminar report

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The purpose of this project is to study, implement, and evaluate existing shepherding algorithms based on various flock properties. In order to do so, we investigate how characteristics such as social heterogeneity of flock influence the convergence and overall effectiveness of herding algorithms. To achieve this, we implement several existing algorithms and evaluate their performance across different flock configurations.

Sheep herding | Flock behavior | Collective behavior

Introduction

Herding of sheep is a classic example of the unwilling movement of a group of individuals with a common goal. As such, it is a unique and fascinating subject for studying. The knowledge obtained might be useful in various fields from security to crowd control.

The motivation for this project arose from the observing of the geometric compactness of flock behavior during the herding process. Many such examples can be found online[1]. Although the process itself appears almost magical, our primary goal is to determine how herding can be carried out as efficiently as possible and to identify the factors that most strongly influence its effectiveness.

Related work

Numerous studies examining the behavior of flocks of sheep. Our primary reference is the paper by Jadhav et al. [1], in which the authors developed a model based on spatiotemporal data from a flock of 14 sheep. However, this approach has several limitations, including the small flock size and the lack of consideration of flock heterogeneity. As Bennett et al. demonstrated in [2], heterogeneity within social groups can negatively affect herding performance. In this paper, the authors developed multiple non-overlapping social groups and measured the herding performance. With increasing the number of subgroups, the performance decreased. The subgroups are mainly defined by two weighted forces: the force to interact with other sheep and the force to be repulsed from a dog.

There are also many existing studies that modeled the herding algorithms. Back in 2014, Daniel Strömbom et al. [3] presented an algorithm based on real world data that worked with attraction–repulsion herding. The algorithm is based on dynamical switching between two modes: collecting the sheep when they are too dispersed, and driving them to the goal when they are cohesive.

In a newer study by Cai et al. [4], the authors present four herding algorithms that are also based on repulsion and attraction. However, to reach their goals, they introduce far-end and pausing mechanisms that dynamically adjust the target point of a herd and pause to optimize control and prevent circling, respectively.

Methods

To achieve the goal of this project, we are going to implement the original algorithm from [1], the Herding Algorithm With Dynamic Far-end and Pausing Mechanism introduced in [4] and the Strömboms algorithm [3] for reference. Additionally, we divide the sheep into social subgroups based on the repulsion and attraction forces inspired by ideas described in [2].

To conduct the experiments, we will fine-tune the parameters and execute distinct flock configurations across different algorithms. The primary objective is to identify

We study, compare and compare existing sheep herding algorithms to find the optimal flock configuration which could increase the effectiveness of herding procedure.

[1] https://www.youtube.com/watch?v=tDQw21ntR64

optimal settings that allow each algorithm to converge as fast as possible while maintaining high flock cohesion.

In this iteration, we implemented the Strömbom algorithm [3] alongside the original model. We also developed a simple framework to perform experiments, measuring and plotting three critical flock metrics over time. The following section outlines these two algorithms.

Original model. This algorithm calculates movement vectors for both sheep and herding dog using spatiotemporal data. The sheep's motion is driven by the following parameters:

1. repulsion from the other sheep,
2. attraction to the center of local neighbors,
3. alignment of the velocity direction to the average of neighbors,
4. repulsion from the dog,
5. random noise.

On the other hand, the movement of the shepherd is divided into two separate stages:

1. **Collecting:** the dog moves to collect stray sheep.
   This mode takes place when the group is not cohesive.
2. **Driving:** the dog moves behind the herd to push it forward.
   This mode occurs when the group is cohesive.

Strömboms algorithm. This algorithm shares many similarities with the original model, defining movements for individual sheep and the herding dog separately. It also utilizes the same two operational modes for the shepherd: collecting and driving.

However, a significant difference distinguishes Strömbom's algorithm: it incorporates a grazing movement when the dog is sufficiently distant from the sheep. This property may enhance overall group cohesion, as the net displacement of the flock becomes insignificant. In case of herding, the movement of the individual sheep is influenced by the following factors:

1. repulsion from the other sheep,
2. attracted to the local center of mass of n nearest neighbors,
3. repulsion from the dog.

The list of parameters of both algorithm described above is not complete, but contain only the most important ones.

In summary, both algorithms operate on the same fundamental principle. In each iteration, new sheep positions and headings are calculated based on the dog's location and the aforementioned parameters. Once the sheep states are updated, the dog's new position is computed relative to the flock. This calculation relies on above described parameters e.g. the sheep repulsion radius in the original model versus the sheep-sheep repulsion distance in Strömbom's algorithm.

Results

So far, we have successfully implemented and run the original simulated the running original algorithm from [1] and Strömbom algorithm proposed in [3]. We used the following experimental parameter setup for both algorithms:

- Flock size: 30 sheep
- Field dimensions: 100×100 units
- Duration: 2000 iterations per simulation

Other algorithm-specific parameters, such as repulsion radius or dog detection range, were set to the default values from the source literature.

The flock dynamics were evaluated based on three distinct properties: cohesion (quantified as the mean distance to the barycenter), polarization (velocity alignment), and elongation (the length-to-width ratio). The statistical properties of each metric for both algorithms are summarized in the tables 1, 2 and 3.The evolution of each metric during the simulation is depicted in Figure 1.

We observe that although the cohesion and polarization values in the original model are consistently higher throughout the simulation, the group elongation remains notably low. This is mainly due to the sheep behavior, when the dog is away. The Strömbom algorithm employs a grazing phase characterized by small, random movements that keep the flock relatively stationary. In contrast, the original model lacks this mechanism. Without attraction towards the center or alignment forces in this state, the sheep exhibit more dispersed movement.

Table 1. Statistical characteristics of flock cohesion (mean distance to group center in m) by algorithm

Algorithm	Mean	Std Dev	Min	Max
Strömbom Model	22.5533	26.2588	2.3552	95.4500
Original Model	45.5906	25.7619	1.2988	91.5578

Table 2. Statistical characteristics of polarization (velocity alignment) by algorithm

Algorithm	Mean	Std Dev	Min	Max
Strömbom Model	0.4953	0.2293	0.0152	0.9155
Original Model	0.7649	0.0627	0.2134	0.9655

Table 3. Statistical characteristics of elongation (length/width ratio) by algorithm

Algorithm	Mean	Std Dev	Min	Max
Strömbom Model	1.3535	2.0264	0.0546	19.0175
Original Model	0.6196	0.1025	0.5137	1.0647

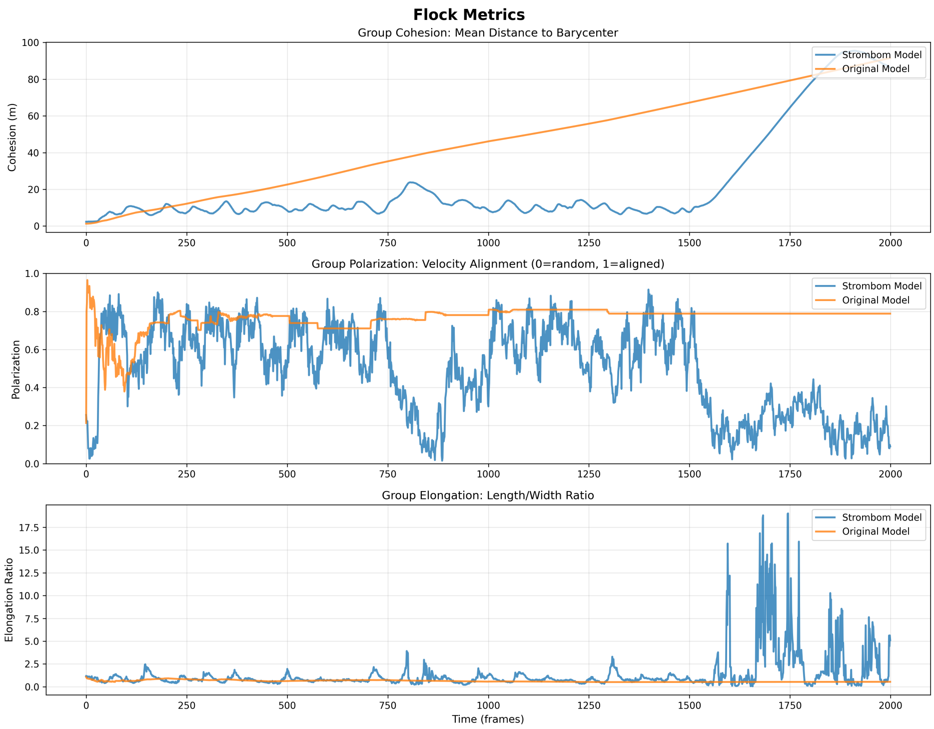

Figure 1. Comparison of cohesion, polarization and elongation in each iteration.

Discussion

The project is progressing according to the plan. The code is easily modifiable to add new herding algorithms and measure their properties. In the rest of the project, we will focus on the following challenges:

1. Implement the heterogeneous social groups among the sheep flock,
2. Tune the parameters of both models to achieve the model with the highest cohesion,
3. Based on the cohesion measurement, create an algorithm that can make the flock both cohesive and move from point A to point B in the least amount of steps possible.

CONTRIBUTIONS. **JF** wrote the report, **OG** implemented the Strömbom algorithm, **MM** developed the framework for performing experiments and saving their results.

Bibliography

1. Jadhav V, Pasqua R, Zanon C, et al. (2024) Collective responses of flocking sheep (ovis aries) to a herding dog (border collie). *Communications Biology* 7(1543).
2. Bennett C, Bullock S, Lawry J (2021) Demonstrating the differential impact of flock heterogeneity on multi-agent herding in *Towards Autonomous Robotic Systems*, eds. Fox C et al. (Springer International Publishing, Cham), pp. 147–157.
3. Strömbom D et al. (2014) Solving the shepherding problem: heuristics for herding autonomous, interacting agents. *Journal of the Royal Society Interface* 11:20140719.
4. Cai H, He Y, Wu J, Gao H (2023) Behavior-based herding algorithm for social force model based sheep herd. *Electronics* 12(2).