Evolving Cutting Horse and Sheepdog Behavior in a Simulated Flock

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Abstract

The focus of this project is attempting to evolve the behavior of a single agent or small group of agents so that they can effectively direct the movement of a much larger group. This is very similar to the roles cutting horses and sheepdogs take to manage livestock. Emphasis is placed on realistic flocking behavior and evolution of a a simple set of rules to manage the herding. reduce the complexity of controlling these real and simulated characters and to provide computationally feasible solutions.

1 Introduction

In the course of farming, humans have trained some of the more intelligent creatures to control a herd of livestock or flocks of poultry through planned movement. The sheepdog and the cutting horse are two good examples of this behavior. The sheepdog is used to herd and guard sheep, but the focus of their training is on moving a herd. The cutting horse is used with cattle, to "cut" a single cow off from the herd, allowing farmers to access it. The principal of using a specially instructed single agent, or a small group of agents, to direct the movement of a large group of agents presents an interesting challenge.

This project aims to develop instructions for these specialized agents without explicitly programming it. Since the nature of different herds varies based on a variety of factors, such as the species of the animals, their health, conditions, and environmental factors, it would be helpful to have a dynamic system for creating this sheepdog behavior, to allow for a later, robotic herding agent to adapt to different conditions. There is also the possibility of discovering new techniques for controlling the movement of the herd, which could be applied to real life. Any behavior that is likely to be evolved should be easily reproducible, since it will use several vectors calculated from the sight of the sheepdog. The flocking behavior relies on three simple rules, and for the sake of symmetry the hoped for herding behavior will be just as simple.

In addition, it would be interesting to explore methods that a group of coordinated sheepdogs might use to direct a flock more efficiently. From what I have gleamed from my research, sheepdogs might be used together, but the farmer directs each one independently; the dogs do not coordinate. It's possible that cooperation could lead to much more efficient techniques.

2 Previous Research

There has not been very much research directly in this field. The main focus of past research has been on flocking, which is similar to a flock of birds flying at high speed. There have been a limited number of simulations of a stationary herd, but the flocking algorithm is flexible, and seems to cover both behaviors well. There have been a few projects dealing with manipulating the flocks, but none of them were very focused on the behavior aspect of the manipulative agent.

3 Robotic Sheepdog Project

The Robotic Sheepdog Project experimented with two different rule-based behaviors for their sheepdog agent. They were moderately successful, but their example really relies on an enclosed field with walls to "guide" the flock towards the goal. The Robotic Sheepdog Project does serve as a proof of concept, namely that it is possible to effectively control livestock with a robotic agent. The ducks that they used responded to the robot in a consistent and predictable manner. At one point during their experimentation, a stuffed fox was mounted on the robotic agent. By their accounts, the presence of the predator visibly upset the ducks, and they did not react as well as they had to the non-predatory simple robot. This might hold in other cases, which would mean a robotic sheepdog could offer a way of controlling a herd in a way less stressful to the livestock. Using a dog to herd ducks and sheep may be inherently stressful, as a dog is a natural predator to these animals. If a robotic agent could reduce the "worrying" of the livestock, it could increase the worth of the livestock.

4 Flocking

Flocking behavior has three components to the algorithm They are separation, cohesion and alignment. Seperation is moving to keep a minimum distance away from the nearest flockmate. Cohesion is attempting to move towards distant flockmates. Alignment is a changing direction of motion to match the direction of nearby flockmates.

A stationary flock follows the same rules that a moving flock does. The vectors were scaled down so the flock would come to a halt. It was important not to scale them down too much, otherwise the flock would loose responsiveness to the sheepdogs. The variables were hand-adjusted to be right on the cusp of having the flock constantly in motion. As soon as the bugs were worked out, it was observed that the stationary flock behavior produced was very similar to that exhibited by actual stationary flocks, such as a flock of grazing geese. The boids seemed to flow around a predator who approached them, and would reform into one mass after the predator had passed. This was very encouraging.

5 Sheepdog Behavior Methods

Initially, I expected to use neural networks to determine the behavior of the sheepdogs. This would have been a good approach because it would allow for many, many different kinds of behavior to emerge, including non-intuitive ones. Unfortunately, it turned out that using neural networks was not realistic, as implementing them correctly, and bug shooting them would have doubled or tripled the expected length of the project.

Instead, I choose to use a weighting system for the sheepdogs. Their genetic code determines how much weight they give to a set of pre-calculated vectors. They also have the ability to determine the exponents of the vectors, which greatly increases the possibilities for their behavior. A genetic code could make one vector be calculated on an inverse square system, while another is a linear square.

Though there are compromises in limiting the possible end behaviors, the weighting method is a good choice. Because of the way it is set up, any successful behaviors will be able to be expressed in similar language as the flocking algorithm. This makes the behavior versatile, it can be implemented anywhere, again and again, instead of relying on a specific neural network producing using cryptic methods.

Currently, the weighing method has been implemented, at least in it's first iteration. A whole 10000 separate genetic codes have been generated, comprising the gene pool for the first generation. So far, no automated trials have been programmed, but they soon will be. I should be producing my first results by the end of February.

6 Prelinary Results and Screenshots

The evolution program, and the herding simulator will be both written in python. TKinter will be the graphical display system used. Here are some preliminary screen shots.

7 Results

The project is by no means completed, but by halfway though the third quarter, some preliminary trends have become apparent. There were three working populations running at the same time during this stage of the project, two with the same genetic system, and the third with an extra gene that allowed the sheepdogs to set a maximum speed for themselves.

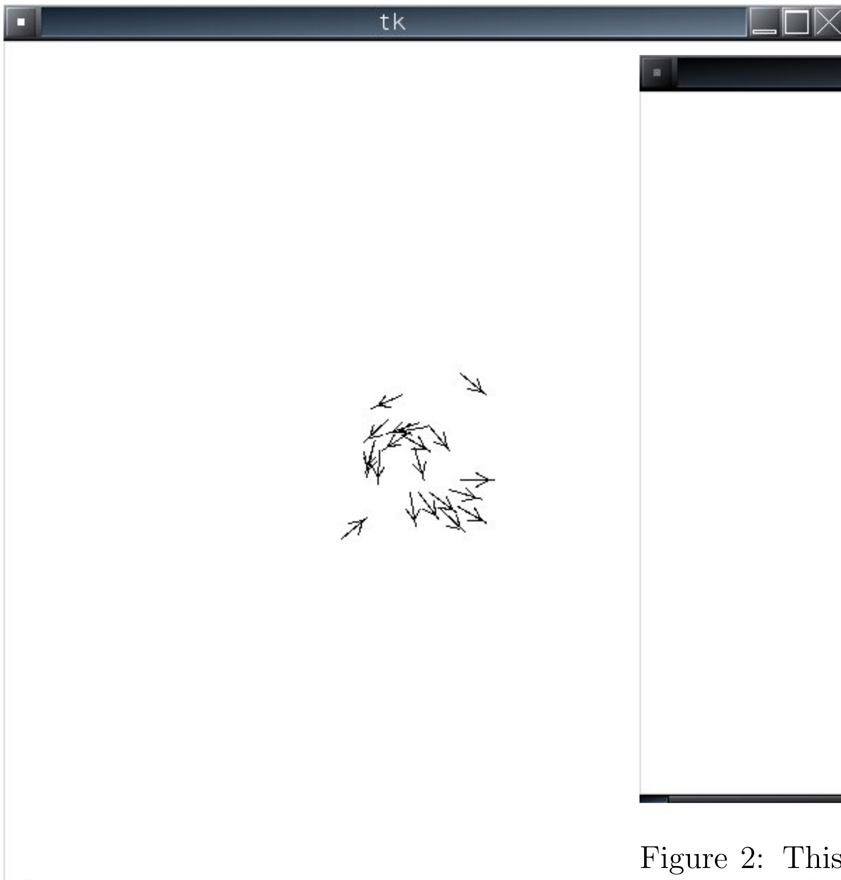

Figure 1: This figure shows a very early (Q1) flock. It is chaotic, the flocks had not been stabilized to herds yet.

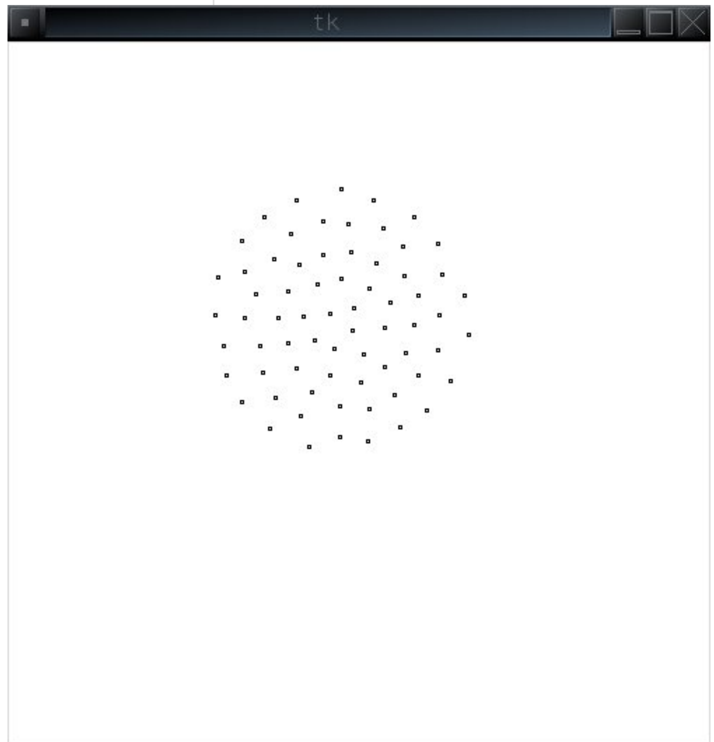

Figure 2: This is the correct herd behavior. Because of a bug in the code dealing with angle inversion, it wasn't until December that this behavior emerged.

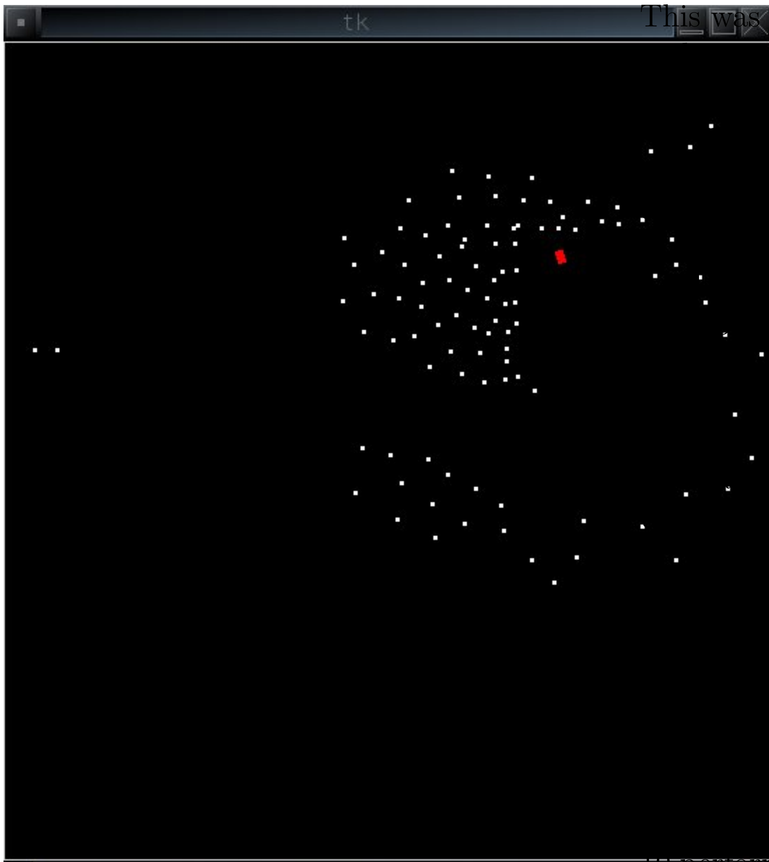

Figure 3: TThis figure shows the flock's correct response to the presence of a predator (red) in their midst. They are being herded, but they also slide around the predator, and reform the flock. This behavior was elusive due to several hidden bugs in the code.

In the first population, the predominant strategy was for the sheepdogs to insert themselves into the center of the flock, and move in a spiral while slowly inching towards the goal. This was effective, though maybe an entirely
ethod for moving the sheep. The
nds around the sheepdog, forming
n that looks like a bubble. I have
that this is similar to the behavior
se, so some variation of this method
st likely work in reality.

ond population is a little more stan-
vior to what we think of as sheep-
se sheepdogs chase the flock down
moving back and forth to direct
s back into the herd. They suffer
oblem induced by the simulation -
sionally loose their flock and wander
mlessly. The simulation has an arti-
v barrier for sheepdog sight, which
uring testing to make the testing
later populations, this barrier will
d.

st exciting thing about the second
n's strategy is that it works even
en more dogs are added. The top
10 performing dogs from the third generation will chase the sheep down the field and into the goal in a matter of seconds, resulting in a display that is almost majestic to behold. It is possible that in later populations, this will be selected for, and that might even progress to evolving 5 or 6 populations at the same time and in the same trials. The goal would be that they could evolve complimentary behaviors, and form a very effective team to herd the sheep.

The third population is the one that has the extra gene that controls speed. This gene is taken advantage of in this population, because the dominant strategy is to move slowly behind the sheep, and gradually approach the goal. This was disappointing to see emerge as a strategy, though it is a realistic strategy for herding. Later populations might be aimed at fast solutions rather than accurate solutions. On an actual field, the faster a sheepdog can move the flock, the more useful it is.

In short, at this point in the simulation, much more testing and trials are desired. It is fortunate, then, because there is enough time to run them.

8 Sources

Many sources were consulted in the design of this project. Some of the more useful ones are listed below.

Flocks, Herds, and Schools: A Distributed Behavioral Model, Craig Reynolds

Low Stress Methods for Moving and Herding Cattle on Pastures, Paddocks, and large Feedlot Pens, Temple Grandin

The robotic sheepdog project:

Robot Sheepdog Project achieves automatic flock control, in Proceedings of the International Conference on Simulation of Adaptive Behaviour, Zurich, Switzerland (1998).

Robot control of animal flocks, in Proceedings of the International Symposium on Intelligent Control, Gaithersburg, Maryland, USA (1998).

Experiments in Automatic Flock Control, Journal of Robotics and Autonomous Systems 31:109-117, April 2000, Elsevier Science BV.