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Family Bird: A Heterogeneous Simulated Flock

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Abstract

Since the phenomena of bird flocking is so fascinating, there is no shortage of computer models that try to visualize this mesmerizing spectacle. However, the quality of artificially modelled flocks is currently not on par with their counterparts in nature. We believe the main reason for this lies in the homogeneous structure of flocks in computer models. In this article we show how just a pinch of heterogeneousness can increase the repertoire of displayed behaviours.

Introduction

At first glance the mesmerizing phenomena of bird flocks and fish schools appear very complex, but according to existing literature the underlying principles may be quite simple. In 1980s two groups of researchers working independently showed that a flocking-like behaviour can be produced in computer simulations if artificial animals (*animats*) follow a few simple rules (Reynolds, 1987; Heppner and Grenander, 1990). Reynolds introduced three drives – *cohesion*, *separation* and *alignment*. Cohesion drives the observed animat to stay close to its neighbours; separation forces it to avoid collisions by steering away from animats that are perceived as too close; alignment imitates the desire to synchronize speed and heading with nearby animats.

The main problem of models that use these three (or similar) rules is that the appearance of the displayed behaviour is far from the mind-blowing spectacle one might admire in nature. The behaviour of computer produced flocks was very rigid and stereotyped. Many models thus introduced mechanisms that induce some randomness to the motion of the animats (Heppner and Grenander, 1990; Vicsek et al., 1995; Couzin et al., 2002; Hildenbrandt et al., 2010). The authors defend this approach by saying these mechanisms simulate wind gusts, obstacles and other random factors. We disagree with their reasoning since obstacles do not just appear at random, and wind gusts are not random per individual. Even with the addition of randomness the result was nowhere near as breathtaking as flocking in nature; the flocks in computer models seldom split into smaller flocks that rejoin after manoeuvring on their own for a while. We believe the main deficiency of artificial flocks is their assumption that all the birds in the flocks have the same characteristics. The birds in natural flocks often differ in size, gender, age, and even species (Lebar Bajec and Heppner, 2009; Jolles et al., 2013). As shown in (Jolles et al., 2013) the flock's structure and social relationships between individuals greatly impact the behaviour of the flock. To bring computer models closer to flocks in nature, we developed a heterogeneous model that includes social relations.

Methods

Our model uses fuzzy logic to describe the individual bird's drives (Lebar Bajec et al., 2005). These drives depend on a specific number of nearby neighbours, regardless of their distance (Cavagna and Giardina, 2008). Inter-bird occlusion is taken into account, i.e. nearby neighbours occlude those farther away (Kunz and Hemelrijk, 2012). In contrast to other models we have included social relations. We have included two types of animats solitary and social. The separation and alignment are the same for both types, but the cohesion drive is different. For social animats it models the desire to stay close to members of the same social group (e.g. family), for solitary animats it models the desire to stay close to nearby neighbours regardless of their affiliation.

To test the behaviour of the upgraded model we ran several simulations. The length of every simulation was 1800 frames (30 frames equals one second). The flock consisted of 20 animats. During the first simulation all 20 animats were solitary, so the flock was completely homogeneous. In our second simulation we had 15 solitary animats and 5 animats that belonged to the same social group. In our third simulation the flock consisted of 2 social groups with 5 animats in each and 10 solitary animats. Our last configuration had 3 social groups consisting of 5 animats each and 5 solitary animats. The flocks were left to roam freely inside a circular roosting area of 140 body lengths in diameter.

During our simulations we measured the *order* of the group (Vicsek and Zafeiris, 2012) and the number of flocks. We defined a *flock* as a group of animats that have influence on each other's behaviour. So to have two flocks there need to be two groups of animats, in which no one from one group influences the behaviour of an animat in the other group, and vice versa. The order of the group is measured via the normalized velocity φ, which is calculated as

$$\varphi = \frac{1}{N v_0} \left| \sum_{i=1}^{N} \vec{v_i} \right|. \qquad (1)$$

Results

As it can be seen from Figure 1, the behaviour of modelled animats is much more dynamic if the number of social groups is higher and the number of solitary animats is lower (more heterogeneity). The order of a homogeneous flock declines only when it reaches the edge of the roosting area and performs a U-turn. The behaviour is more diverse as well; splits and joins of flocks that consist of more than one social group are quite common and do not appear only at the boundaries of the roosting area.

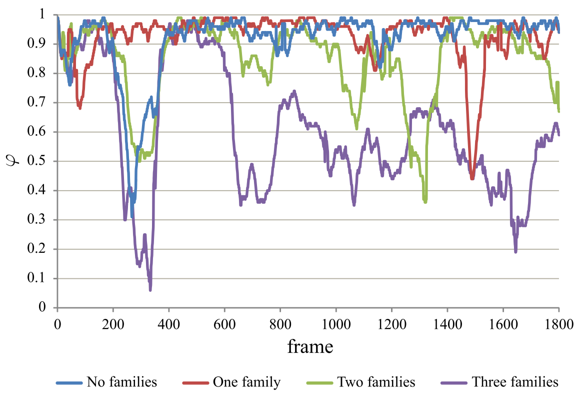

Figure 1: How the value of φ changes through time in differently structured flocks.

But the increase of the number of social groups and the decrease of solitary animats have a downside. A very low number of solitary animats produces separate flocks that fly independently and only seldom rejoin in a larger flock. Figure 2 shows the importance of solitary animats, as they are the main reason of re-joins of split flocks. So the most "natural" results were achieved when the number of solitary animats was the same as the number of social animats. Videos of simulations are available at http://lrss.fri.uni-lj.si/cb/families.html.

Conclusion

Our simulations suggest that homogeneousness might be an important factor for the lack of diversity in the displayed behaviour in computer models. Just with the addition of simple social relationships we managed to achieve complex manoeuvres in the form of splits and joins that resemble natural movements. What could be achieved with more complex heterogeneity is still to be researched.

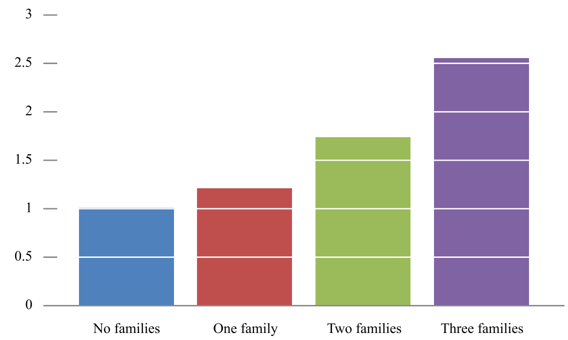

Figure 2: Average number of flocks during our simulations depending on structure of flock.

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