ETHlogo

**Lecture with Computer Exercises:**

**Modelling and Simulating Social Systems with MATLAB**

Project Report

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| Predator-Prey Swarming Model |

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**You MUST include the ETH declaration of originality here; it is available for download on the course website or at**

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# Abstract

In this paper we examine the predator-prey swarming model published by Vladimir Zhdakin and J. C. Sprott in 2010. Firstly, we explain the model and mention all of its variations. Then we compare the results that got published in the paper mentioned above to the new created results to check if the new implementation fits the one made by V. Zhdakin and J. C. Sprott.

Next we discuss how each parameter of the model influences the results, how the parameters should be interpreted and there is an explanation of how they relate to each other.

Another important point is the question which parameters deliver the most realistic results. We determine what range the parameters should be chosen to create a simulation as close to the real world as the model allows.

At last we discuss which aspects of swarming and hunting behaviours of fishes are fulfilled and which are not.

# Individual contributions

Vladimir Zhdakin

J. C. Sprott

# Introduction and Motivations

A fish swarm that is under attack by sharks are spectacular to watch. It moves as a unit to minimize every fish’s risk of getting killed. There are many models that try to describe and examine the movement of the swarm and the predators. One of it is an agent-based model by Vladimir Zhdakin and J. C. Sprott that tries to reproduce the movement by using forces between the agents and friction between every agent and the environment. The model is kept simple at the expense of making it as realistic as possible. There are only a few parameters to make it possible to explore most of the variations in reasonable expenditure of time. Another reason for this simple model is to keep the simulation of swarming independent of specific organisms which would need to include also organism specific parameters and properties.

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# Description of the Model

The model consists of two agents, predators and preys. They are both simulated on a two and three dimensional Cartesian plane. With the three dimensional plane we want to get a more realistic simulation of a swarm and predators. This paper do not explore the case where there is only one predator since the most of these scenarios end in an equilibrium which isn’t realistic.

Because the model will be kept as simple as possible the agents do only interact with the environment via a friction.

All forces between the agents are directed radially from the agents. Prey pairs interact with long range attractive and short range repulsive forces with each other to model the behaviour in a swarm as the single members try to stay at a certain distance from each other. Predator – prey pairs both interact with an anti-Newtonian force.

This model will use three different forces between predator pairs which all occur in nature. First there is no interaction between predators what will simulate attackers which do not hunt or interact with each other. Second is an attractive force between the predators so they can form a group of predators to chase the swarm. Thirdly this paper will explore a repulsive force between the predators. This could be a model of predators trying to attack a swarm from different sides to confuse them. Because the anti-Newtonian force is non conservative the system is able to stay indefinitely in motion.

The long range and short range force fij, gij between agent i due to agent j are given by:

(1)

(2)

(3)

Where is the distance between agent i and j, and are the force parameters for long range attractive and short range repulsive force respectively. The model will use since this will result in the most realistic swarming behaviour. Long range force will only be used for attraction and short range for repulsion.

The resulting force for the motion of a prey is:

Where m is the mass of a prey, b0 the coefficient of friction. The subscript 0 denotes parameters of prey agents whereas x denotes parameters of predators.

An additional restriction to the above formula is . The first sum adds all forces acting on prey i due to all other preys (except i). It accounts the attractive and repulsive forces between the preys that form the swarm. The second summation adds all forces acting on prey i due to all predators which is responsible for the anti-Newtonian. The last term is the friction of the prey and the environment, which is proportional to the velocity of the prey.

Next three forces between predators are considered.

In this formula there is no interaction between the predators. The summation over all preys j is responsible for the force directed in direction of the preys. The last term is the friction which is the product of the predators coefficient bx and it’s velocity.

By choosing a minus or a plus in the first summation considers a repulsion or attraction between the predators respectively. Additional in the repulsive case of predators the short range repulsive force is not essential.

At the beginning of the simulation the predators and preys are distributed randomly in a certain interval on the on the plane. This should approximate a swarm which is unorganised at the beginning.

The choices of the parameters in the model are essential of the behaviour of the swarm. Some of the choices as seen below will give a more realistic behaviour whereas others give odd, not swarming typical behaviour.

# Implementation

# // Simulation Results and Discussion

# Interpretation of the parameters

Here we discuss the different parameters that appear in the model. We figure out how to interpret them and how to choose them to get a realistic simulation.

**The motion parameters α & γ**

These two parameters define two of the forces that apply to the agents. γ defines the attractive force and α defines the repulsive force. In this section we always look at the force between two preys.

The first thing to notice is that they have to be negative. To understand why, we have a look at two agents. It is clear that both, attractive and repulsive, forces between these two preys have to be strong when they are close together; is small, and they have to be weak when they are far apart; is big. To achieve this, we can simply choose negative motion parameters.

The next observation is that α has to be smaller than γ. This follows from the fact that the agents should swarm. The attractive force has to be stronger than the repulsive force when agents are far apart. But when the agents get too close the opposite situation has to appear, i.e. the repulsive force is stronger than the attractive. This prevents agents from swimming into each other. Choosing α to be smaller than γ and using them as exponents on the distance between the agents creates this exact situation. In this case, when the distance between the agents gets smaller than 1, the repulsive force becomes stronger than the attractive force.

To find out how to choose the motion parameters to get a realistic result we examine two properties between them.

Macintosh HD:Users:Jonas:Documents:MATLAB:AlphaGammaDistance.eps

The first property is the difference between α and γ. The effect of this difference can be seen on figure 1. It shows the total force on an agent due to another agent in relation to their distance. When the difference becomes larger the peak of the force curve increases and the curve becomes less flat. This leads to a faster stabilization of the system. For realistic results we found a difference of 1 to be best because it provides the most continuous movement.

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Now that we know the difference between α and γ we investigate the second property which is the value of α. The effect of changing the value of α can be seen on figure 2. It shows the total force on an agent due to another agent in relation to their distance, just like figure 1. The most noticeable effect of changing the value of α is that for distances greater 1 the total force becomes stronger when α becomes greater. For most realistic results we have to take the mass of one agent into account which will be considered below.

**Mass and friction**

# Summary and Outlook

# References