Simulating flock of birds using only vision

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Collective behaviour course research seminar report

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When modeling collective behaviour it is commonly assumed that agents inherently know other agents position, velocity and direction. There exists a motivation to get rid of these assumptions and model the behaviour based on how internal and external information is acquired and processed. Vision is one of the more important sensory systems that provide crucial external information, which turns out to be sufficient for modeling interactions between agents in a swarm. In this seminar we explore a mathematical framework for perception-based interactions proposed by Renaud Bastien and Pawel Romanczuk.

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Models of collective behaviour often rely on interactions that do not have a direct physical reality (such as neighbour velocity, relative position and direction). One example of this is the simulation of fish schools [1]. However, this assumption of how the information is processed by agents limits our understanding of the underlying complexity that takes place in such phenomena. A better alternative would be to model the behaviour around internal and external information that agents are capable of acquiring.

In this seminar we use a mathematical framework proposed by Renaud Bastien and Pawel Romanczuk [2], to create a simulation of flock of birds that solely relies on vision.

Methods

The simulation is done in 2-dimensional space where agents are represented as simple disk objects with full 360° view. On each simulation step, their velocity is modified based on a projection of their surrounding visual field. This simulates a primitive form of vision.

Visual field projection. Objects around the agent are projected onto their visual field, described by $P(\varphi)$. Function $P(\varphi)$ represents visual obstructions of the agent, where φ is an angle of the visual field. The result is binary, where 0 represents "not obstructed" and 1 represents "obstructed". An example of a visual field projection can be seen on figure 1.

Velocity. On each simulation step, the velocity of agent i, is modified by Δv_i. The general speed delta is summarized with the following equation:

$$\Delta v_i = \mathrm{F}_{\mathrm{ind}}(v_i) + \mathrm{F}_{\mathrm{vis}}(P_i) \qquad [1]$$

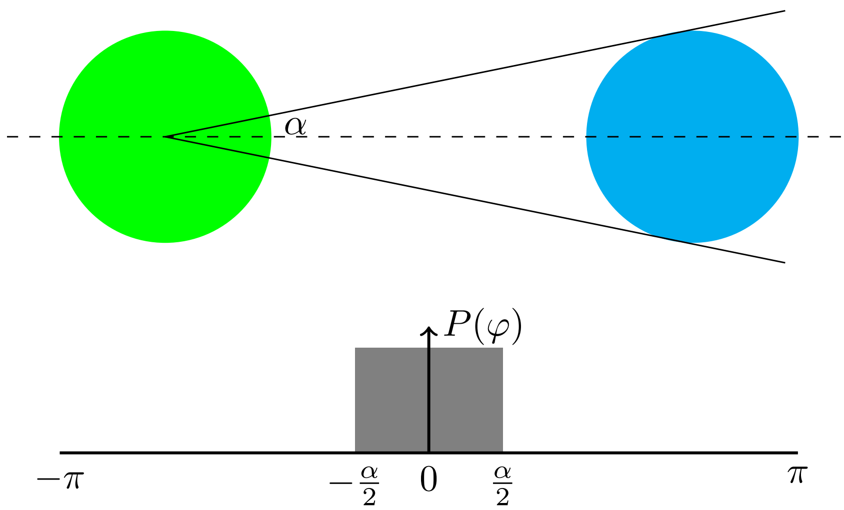

Figure 1. Projection field graph of a single object.

A model of collective behavior based purely on vision

When modeling collective behaviour it is commonly assumed that agents inherently know other agents position, velocity and direction. There exists a motivation to get rid of these assumptions and model the behaviour based on how internal and external information is acquired and processed. Vision is one of the more important sensory systems that provide crucial external information, which turns out to be sufficient for modeling interactions between agents in a swarm. In this seminar we explore a mathematical framework for perception-based interactions proposed by Renaud Bastien and Pawel Romanczuk.

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where $\mathrm{F_{ind}}$ function represents speed delta collected from **ind**ividuals "internal information":

$$\mathrm{F_{ind}} = \gamma(v_{\mathrm{pref}} - v_i)\hat{v_i} \quad [2]$$

where γ represents speed relaxation rate, v_{pref} **pref**erred speed of the individual and $\hat{v_i}$ normalized direction vector. Function $\mathrm{F_{vis}}$ transforms **vis**ual field to the individuals speed delta. It is independent of other individuals properties, and is described with the following equation:

$$\mathrm{F_{vis}}(P) = \int_{-\pi}^{\pi} G(P,\varphi)\ h(\varphi)\ d\varphi \quad [3]$$

Here $G(P,\varphi)$ encodes how information from the visual field impacts the movement, while $h(\varphi)$ encodes properties of the perception-motor system, in our case, it describes how front-back distance impacts the speed and how left-right distance influences the heading direction of an agent. For convenience the equation is split into two parts:

$$\Delta v_i = \gamma(v_{\mathrm{pref}} - v_i) + \int_{-\pi}^{\pi} cos(\varphi)\ \alpha_0 \left(-P_i(\varphi)\ +\ \alpha_1(\partial_\varphi P_i(\varphi))^2\right) d\varphi \quad [4]$$

$$\Delta\Psi_i = \int_{-\pi}^{\pi} sin(\varphi)\ \beta_0 \left(-P_i(\varphi)\ +\ \beta_1(\partial_\varphi P_i(\varphi))^2\right) d\varphi \quad [5]$$

The first (Δv_i) describes speed delta, while the second ($\Delta\Psi_i$) describes heading angle delta. Consequently the heading vector is now removed, since it is encoded as the heading angle.

Implementation. The simulation will be implemented using C/C++. The underlying simulation loop is also parallelizable, as agents are dependant only on the previous state of the simulation, therefore we can use multi-threading to increase the simulation speed, thus allowing us to simulate larger or longer simulations.

Simulation visualisation. Visualisation of the simulation will be done using FFmpeg[1], which will encode an array of pixels (representing a state of the simulation) into an image or a video. The speed of image generation is not important to this seminar and will be done in a separate process. If a need arises, we could use OpenGL for displaying the simulation in real-time.

Results

None yet.

Discussion

Bibliography

1. Huth A, Wissel C (1992) The simulation of the movement of fish schools. *Journal of Theoretical Biology* 156(3):365–385.
2. Bastien R, Romanczuk P (2020) A model of collective behavior based purely on vision. *Science Advances* 6(6):eaay0792.

[1] https://ffmpeg.org/