Data Science Course
Understading swarm behaviour

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Presentation Overview

- All models: sim300.py
- Paper 1: Effective leadership and decision-making in animal groups on the move (Couzin et al)
- Paper 2: Double milling in self-probelled swarms from kinetic theory (Carrillo et al)
- Quantification

All models: sim300.py

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 Models available:
'Simple speed coupling..................smpl'
'Couzin model...........................czn'
'Viscek model...........................vsck'
'Couzin-2 model.........................czn2'
'Mill model.............................mill'
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Paper 1: Effective leadership and decision-making in animal groups on the move (Couzin et al): `czn2`

same as Couzin 1 model but without orientation phase

Paper 2: Double milling in self-probelled swarms from kinetic theory (Carrillo et al): `mill`

A kinetic theory based approach for swarming systems of self-propelled discrete particles.
Individuals driven by self-propelling forces and pairwise attractive and repulsive interactions lead to various morphologies, e.f. flocks, rotating mills, rings and clumps.
We can
- average in direction or velocity
- consider different zones of interaction and averaging (see Couzin et al)

Paper 2: Double milling in self-probelled swarms from kinetic theory (Carrillo et al): `mill`

But: As N=particles grows, it becomes increasingly difficult to follows the dynamics of each individual agent. Therefore, we choose a continuous approach where particles are represented by a density field.
Consider N interacting, self-propelled particles governed by the following equations of motion

$$\begin{aligned} \frac{\partial \vec{x_i}}{\partial t} &= \vec{v_i} \\ m\frac{\partial \vec{v_i}}{\partial t} &= (\alpha - \beta|\vec{v_i}|^2)\vec{v_i} - \vec{\nabla}_i U(\vec{x_i}) \end{aligned} \tag{1}$$

where U is a pairwise interaction potential and $\alpha, \beta > 0$ are values for propulsion and friction forces.

Paper 2: Double milling in self-probelled swarms from kinetic theory (Carrillo et al): `mill`

For U we choose the *Morse potential* which is a common choice for interacting swarming systems

$$U(\vec{x_i}) = \sum_{j \neq i} [\underbrace{-C_a e^{-|\vec{x_i} - \vec{x_j}|/l_a}}_{\text{attraction}} + \underbrace{C_r e^{-|\vec{x_i} - \vec{x_j}|/l_r}}_{\text{repulsion}}] \qquad (2)$$

where C_a, C_r denote attractive and repulsive strengths and l_a, l_r their respective length scales.

Quantification

Quantification `czn2`

Figure 1: Accuracy

Quantification `czn2`

Figure 2: Group elongation

Quantification `czn2`

Figure 3: Two groups

Quantification `mill`

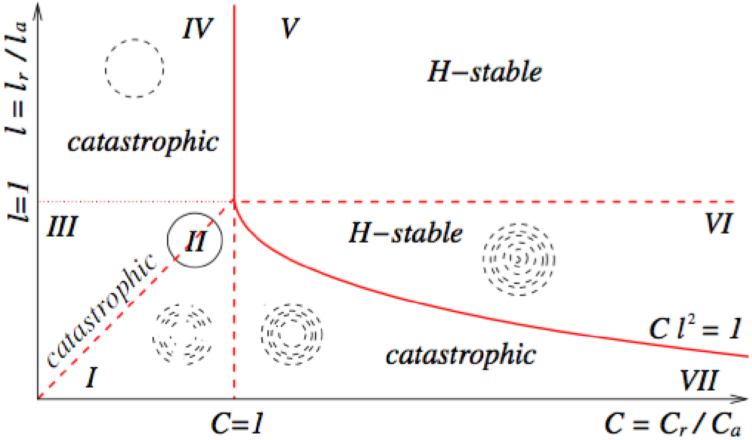

Figure: H-stability phase diagram of the Morse potential

Quantification `mill`

Region I
Region II
Region III
Region IV
Region V
Region VI

Quantification `mill`

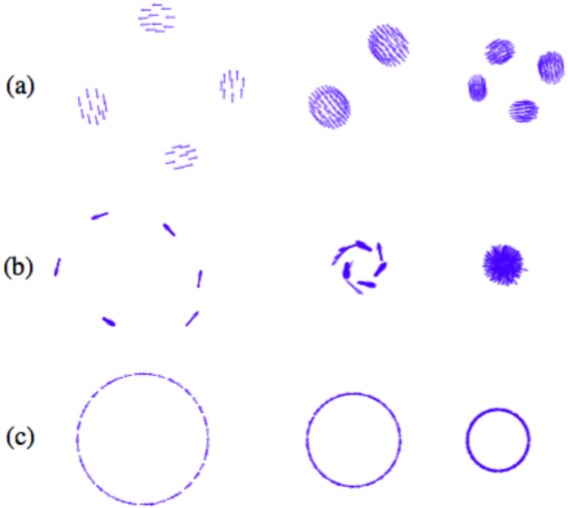

Figure: Catastrophic geometry.
(a) Clumps. (b) Ring Clumping. (c) Rings.

Quantification `mill`

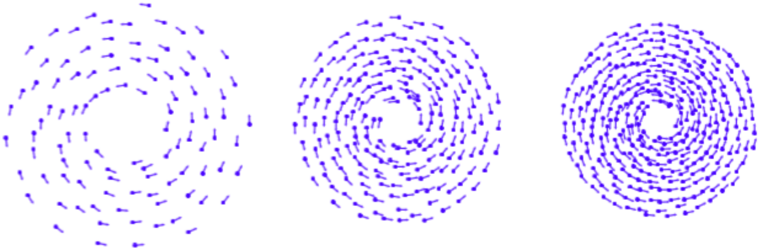

FIG. 3 (color online). Snapshots of swarms for different values of N in the catastrophic regime defined by region VII of Fig. 1. From left to right $N = 100, 200, 300$. The chosen parameters are $C_a = 0.5$, $C_r = 1$, $\ell_a = 2$, $\ell_r = 0.5$, and $\alpha = 1.6$, $\beta = 0.5$.

Quantification mill

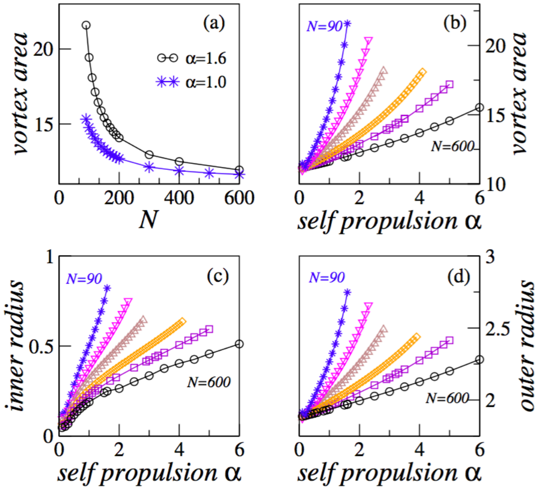

Figure: Vortex scaling for the catastrophic Morse potential.