Data Science Course
Understading swarm behaviour

Felicia Burtscher, Frederik Eistrup, José Senart

Freie Universität Berlin

August 3, 2017

Presentation Overview

- Review past models (simple speed coupling, couzin model, vicsek model)
- Module 1: Effective leadership and decision-making in animal groups on the move (Couzin et al)
- Module 2: Self-Propelled Particles with Soft-Core Interactions: Patterns, Stability, and Collapse (D'Orsogna et al)

Simple speed coupling: weighted speed

Particle adapts a fraction of its nearest neighbour's speed.

Review past models (simple speed coupling, vicsek model, couzin model)

Vicsek model

- introduce interaction zones: repulsion and alignment
- add noise

Couzin model

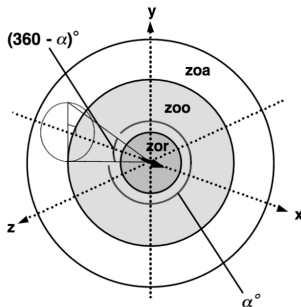- different zones of neighbourhoods: repulsion, orientation, attraction

Figure: Representation of an individual in the model centred at the origin: *zor* = zone of repulsion, *zoo* = zone of orientation, *zoa* = zone of attraction. α = field of perception

We introduce a bias: orientation of ≥ 1 particle (the "informed" one/ "scout").

THEORY

New parameters: weight of bias, proportion of bias, group direction

Goal: Which parameter sets give a nice group movement, and how does the behaviour change when we change the parameters?

IMPLEMENTATION

- periodic boundary conditions
- virtual interaction of agents
- explicit Euler method: $v_{t+1} = v_t + \Delta t \cdot f(t_n, v_t)$

SIMULATION on specific parameter set

QUANTIFICATION

- Accuracy
- Group elongation
- Two scouts

SIMULATION optimised

Module 2: Self-Propelled Particles with Soft-Core Interactions: Patterns, Stability, and Collapse (D'Orsogna et al)

Motivation: Simulate swarming of multiagent systems in order to understand the operating principles of natural swarms, e.g. swaring behaviour of *M. xanthus* cells.
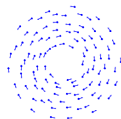
We choose a **kinetic theory** based approach.

The model traits are:
- self-propulsion
- friction
- interaction between particles: repulsion and attraction

Module 2: Self-Propelled Particles with Soft-Core Interactions: Patterns, Stability, and Collapse (D'Orsogna et al)

Consider N interacting, self-propelled particles governed by the following equations of motion

$$\frac{d\vec{x_i}}{dt} = \vec{v_i} \tag{1}$$

$$F = m\frac{d\vec{v_i}}{dt} = (\alpha v - \beta|\vec{v_i}|^2)\vec{v_i} - \vec{\nabla}_i U(\vec{x_i}) \tag{2}$$

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

Module 2: Self-Propelled Particles with Soft-Core Interactions: Patterns, Stability, and Collapse (D'Orsogna et al)

For U we choose the *Morse potential*

$$U(\vec{x_i}) = \sum_{j \neq i} [\underbrace{-C_a e^{-|\vec{x_i} - \vec{x_j}|/l_a}}_{\text{attraction}} + \underbrace{C_r e^{-|\vec{x_i} - \vec{x_j}|/l_r}}_{\text{repulsion}}] \qquad (3)$$

where C_a, C_r denote attractive and repulsive strengths and l_a, l_r their respective length scales.
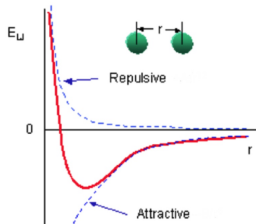
Module 2: Self-Propelled Particles with Soft-Core Interactions: Patterns, Stability, and Collapse (D'Orsogna et al)

IMPLEMENTATION

- rigid boundary conditions
- no virtual interactions
- initial conditions of random distribution
- explicit Euler method to solve the ODEs

Module 2: Self-Propelled Particles with Soft-Core Interactions: Patterns, Stability, and Collapse (D'Orsogna et al)

SIMULATION
INSERT one example simulation

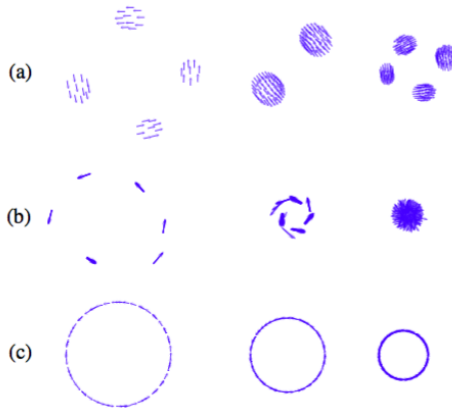# Module 2: Self-Propelled Particles with Soft-Core Interactions: Patterns, Stability, and Collapse (D'Orsogna et al)

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

Module 2: Self-Propelled Particles with Soft-Core Interactions: Patterns, Stability, and Collapse (D'Orsogna et al)
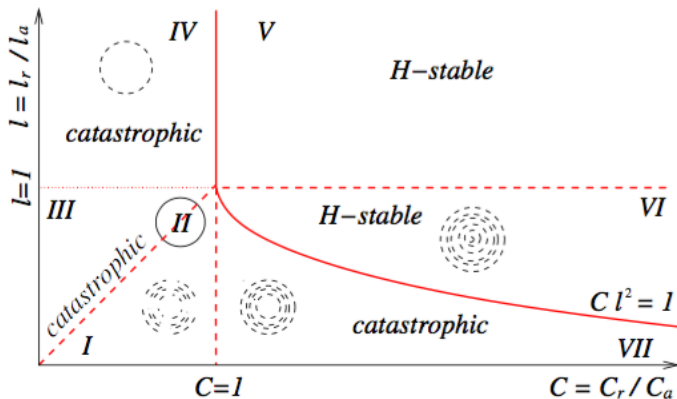

Figure: H-stability phase diagram of the Morse potential

Module 2: Self-Propelled Particles with Soft-Core Interactions: Patterns, Stability, and Collapse (D'Orsogna et al)

INSERT own simulations

Module 2: Self-Propelled Particles with Soft-Core Interactions: Patterns, Stability, and Collapse (D'Orsogna et al)

QUANTIFICATION

- parameter sets for different regions
- testing interesting trends, e.g. $R \propto \frac{\alpha m}{\beta N}$ (from setting $F_{centrifugal} = F_{centripetal}$)
- $\vec{v}^2 \xrightarrow{n \to \infty} \alpha/\beta$ coming from $(\alpha - \vec{v}^2\beta)\vec{v} = 0$ for steady state
- confirmation of ring formation
  - $R_{max}, R_{mean}, R_{min}$ converge to same value
  - $v_{radial} \to 0$ and $v_{tangential} \to |v|$ for $N \to \infty$
- (trend of N, e.g. in simulation of region VII)