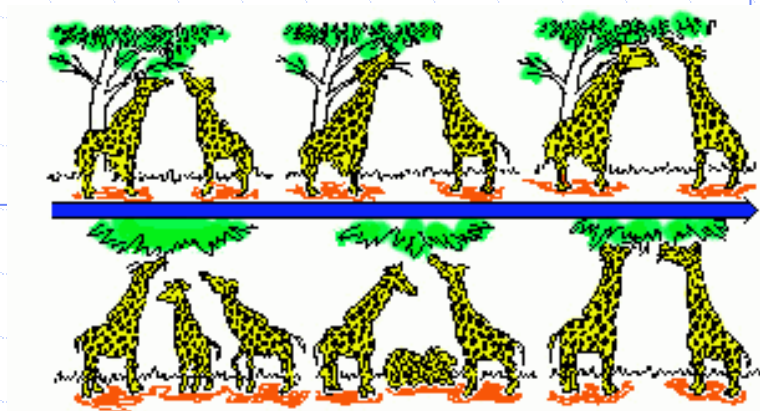


Collective Memory and Spatial Sorting in Animal Groups

東京大学大学院
工学系研究科
電気系工学専攻
伊庭斉志



Iain Couzinによるモデル

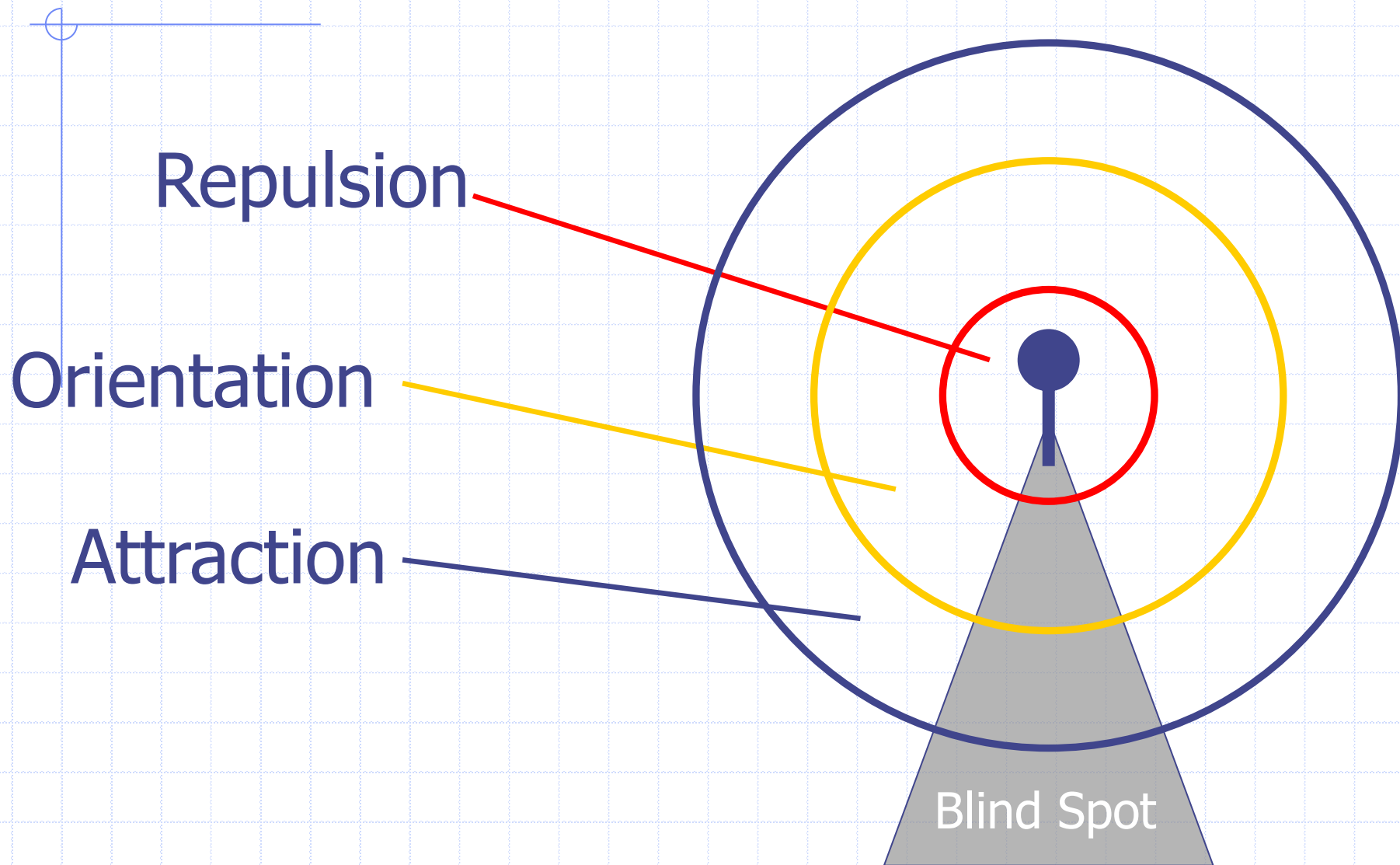
- ◆ より現実的なBoidsを作りたい
- ◆ Collective memoryを実装する
 - 集団構造の過去の履歴が個体間の相互作用に影響する
- ◆ 参照ビデオなど
 - http://youtu.be/_2WqH_HUxz8
 - <http://icouzin.princeton.edu/>
 - <http://vimeo.com/31158841>

Collective Memory and Spatial Sorting in Animal Groups,
Iain D. Couzin^{nw}, Jens Krause^w, Richard James^{sz}, Graeme D. Ruxton^y
and Nigel R. Franks^{sz}, J. theor. Biol. (2002) 218, 1–11.

モデルの基本原則

- ◆ Rule1: 全個体は常にお互いに最初距離を維持する(回避行動)
 - 最大の優先度
 - 実際の生物で観測される行動である
- ◆ Rule2: もしも上の規則を遂行しないならば、他の個体に惹きつけられやすく、かつ近隣個体と並ぶ傾向がある
 - 孤立化を避ける

個体の周囲のモデル化



個体の周囲のモデル化

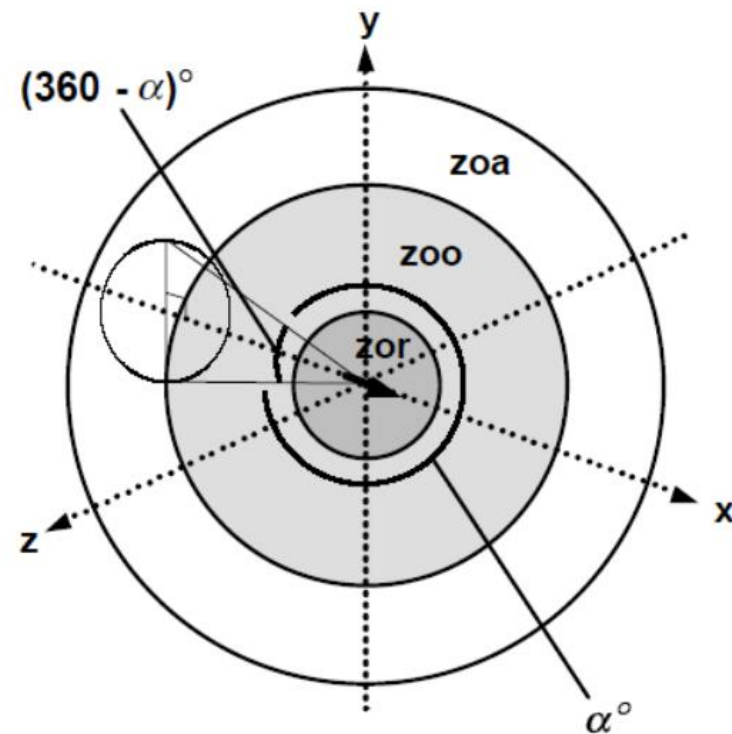
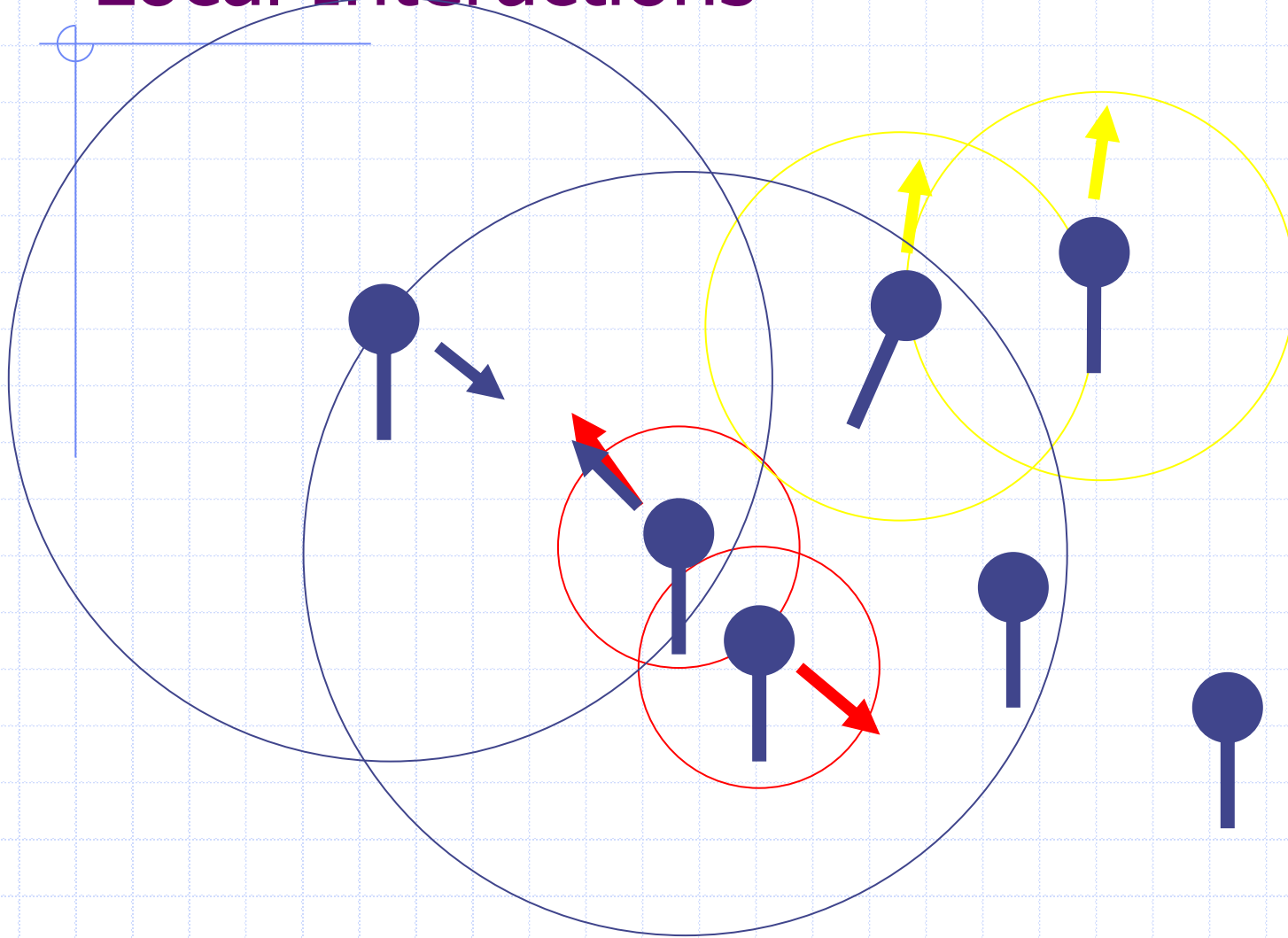


FIG. 1. Representation of an individual in the model centred at the origin: *zor* = zone of repulsion, *zoo* = zone of orientation, *zoa* = zone of attraction. The possible "blind volume" behind an individual is also shown. α = field of perception.

Local Interactions



更新ルール (1)

◆ Zor (zone of repulsion) に個体がいるとき

$$\mathbf{d}_r(t + \tau) = - \sum_{j \neq i}^{n_r} \frac{\mathbf{r}_{ij}(t)}{|\mathbf{r}_{ij}(t)|},$$

Zorにいる個体数

$$\mathbf{r}_{ij} = (\mathbf{c}_j - \mathbf{c}_i) / |\mathbf{c}_j - \mathbf{c}_i|$$

個体j方向への単位ベクトル

$\mathbf{d}_i(t + \tau)$ 次に動くべき方向

◆ 最大の優先度

更新ルール (2)

◆ Zor (zone of repulsion)に個体がないとき

■ Zooに対して

$$\mathbf{d}_o(t + \tau) = \sum_{j=1}^{n_o} \frac{\mathbf{v}_j(t)}{|\mathbf{v}_j(t)|}$$

Zooにいる個体数

■ Zoalに対して

$$\mathbf{d}_a(t + \tau) = \sum_{j \neq i}^{n_a} \frac{\mathbf{r}_{ij}(t)}{|\mathbf{r}_{ij}(t)|}$$

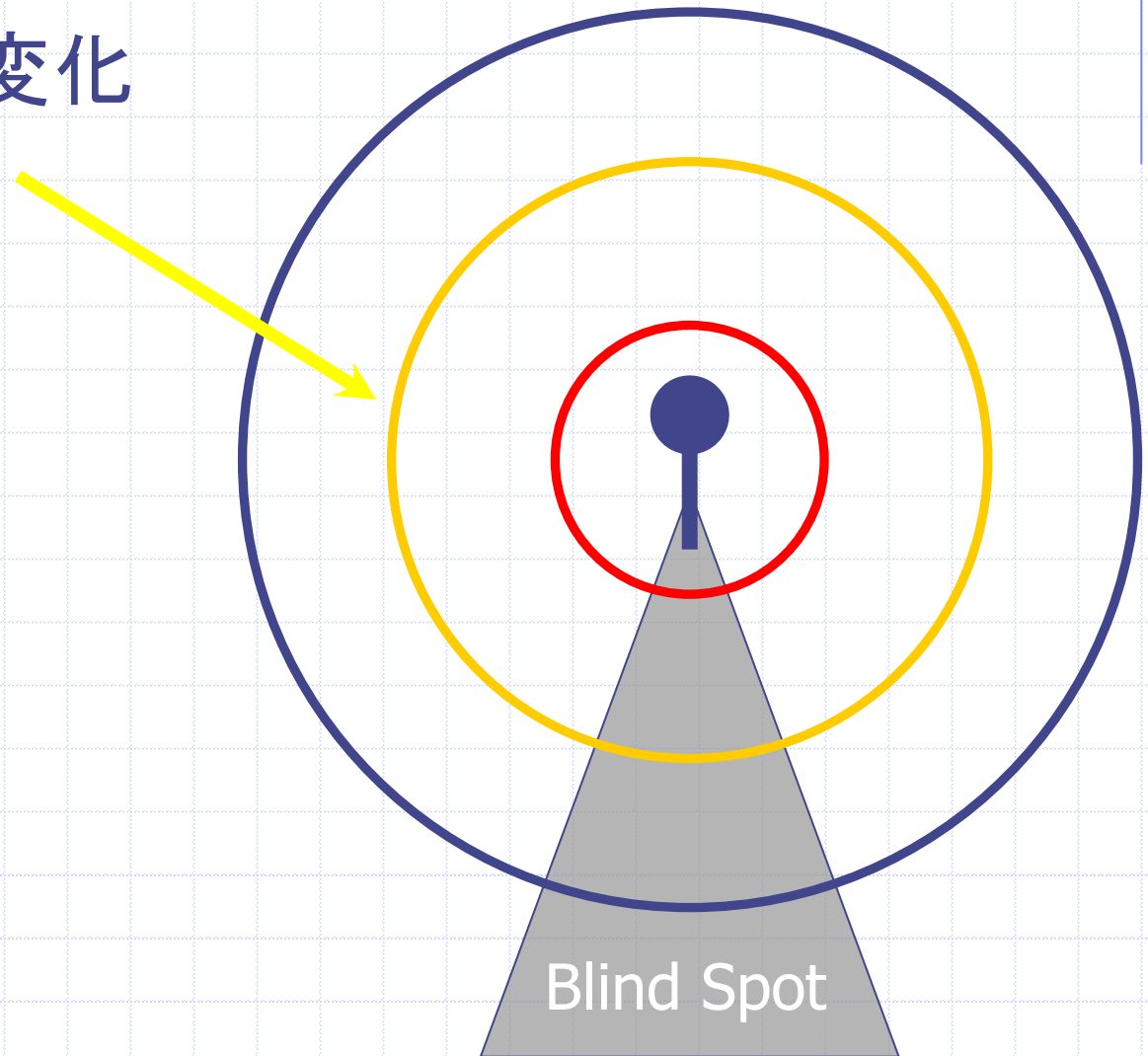
$$\mathbf{r}_{ij} = (\mathbf{c}_j - \mathbf{c}_i) / |(\mathbf{c}_j - \mathbf{c}_i)|$$

個体j方向への単位ベクトル

◆ ただしこれはblind spot を除いて求める

Blind spot

◆ Zooの領域は変化する



更新ルール (2): 続き

◆ Zooのみに個体がいるとき

次に動くべき方向 $\mathbf{d}_i(t + \tau) \longleftarrow \mathbf{d}_o(t + \tau)$

◆ Zoaのみに個体がいるとき

$\mathbf{d}_i(t + \tau) \longleftarrow \mathbf{d}_a(t + \tau)$

◆ 両方に個体がいるとき

$\mathbf{d}_i(t + \tau) \longleftarrow \frac{1}{2}[\mathbf{d}_o(t + \tau) + \mathbf{d}_a(t + \tau)]$

◆ いずれにも個体がないとき

$\mathbf{d}_i(t + \tau) \longleftarrow \mathbf{v}_i(t)$

更新ルール：最後の調整

- ◆ $\mathbf{d}_i(t + \tau)$ をランダムな角度分動かす
 - ガウス分布、標準偏差は σ
- ◆ 各個体 i は $\mathbf{v}_i(t + \tau) = \mathbf{d}_i(t + \tau)$ によって方向を変える
 - ただし、最大の回転角 $\theta\tau$ を超えるときは、この角度までとする
- ◆ 各個体の移動速度は一定の s とする

シミュレーションのパラメータ

TABLE 1

Summary of model parameters. The use of “units” relates to the non-dimensionality of certain parameters in the model with the characteristic length scale being associated with the particular organism in question, e.g. r_r may be very small for an insect, and the rest of the model parameters can be scaled appropriately

Parameter	Unit	Symbol	Values explored
Number of individuals	None	N	10–100
Zone of repulsion	Units	r_r	1
Zone of orientation	Units	$\Delta r_o(r_o - r_r)$	0–15
Zone of attraction	Units	$\Delta r_a(r_a - r_o)$	0–15
Field of perception	Degrees	α	200–360
Turning rate	Degrees per second	θ	10–100
Speed	Units per second	s	1–5
Error (S.D.)	Degrees (rad)	σ	0–11.5(0–0.2 rad)
Time step increment	Seconds	τ	0.1

実験結果

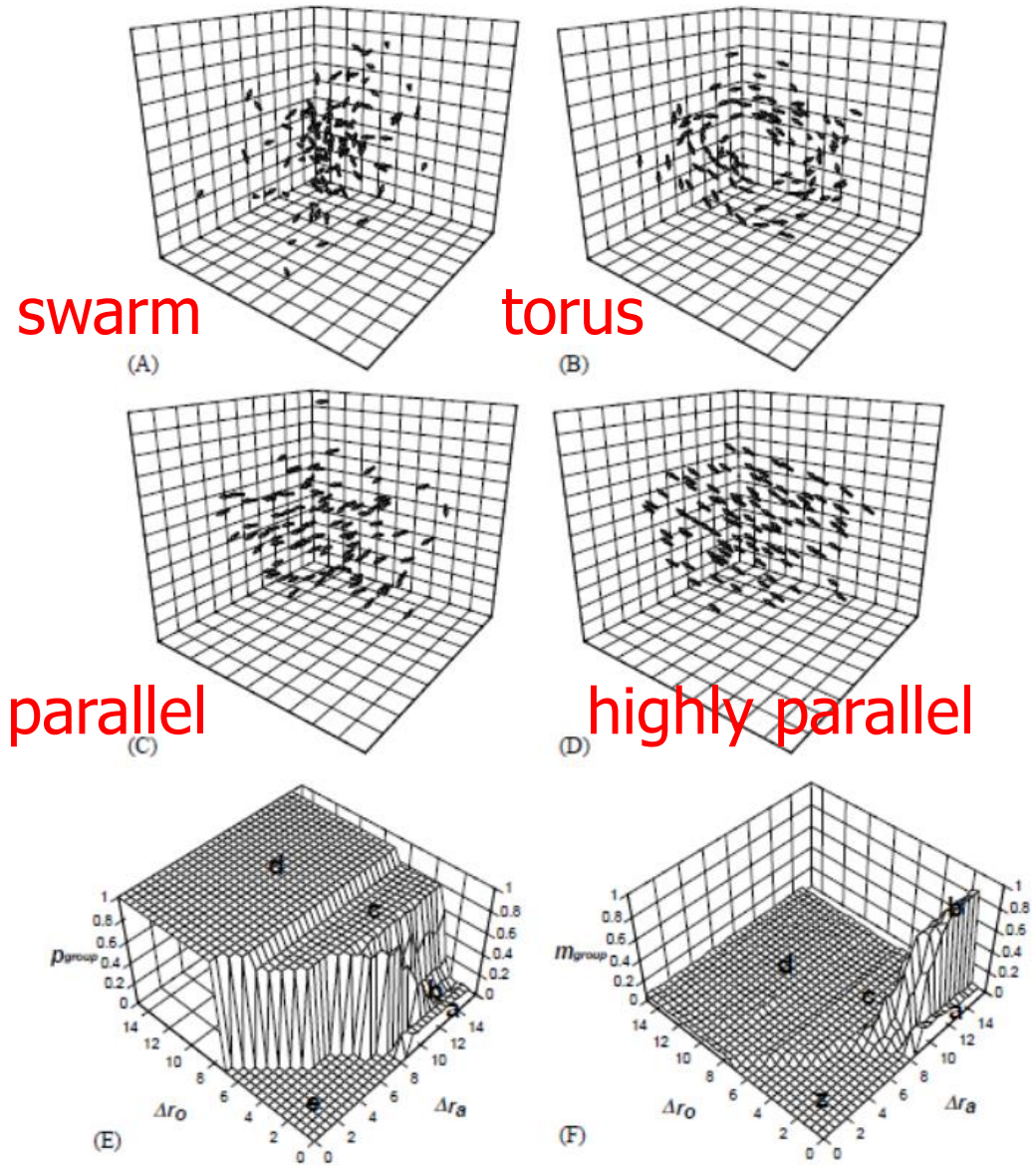
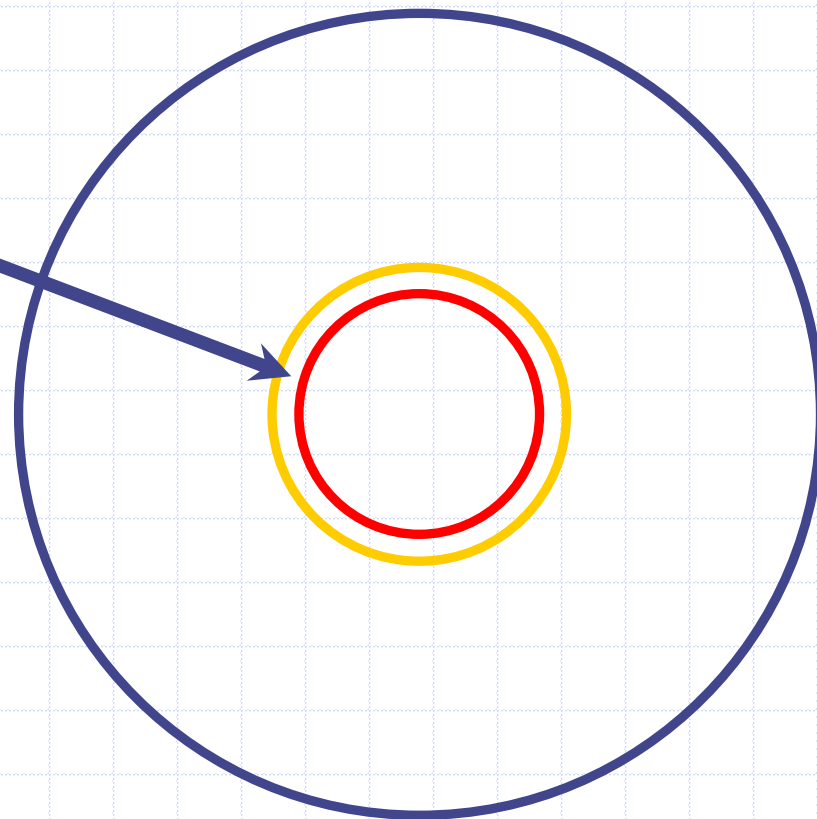


FIG. 3. The collective behaviours exhibited by the model: (A) swarm, (B) torus, (C) dynamic parallel group, (D) highly parallel group. Also shown are the group polarization p_{group} (E) and angular momentum m_{group} (F) as a function of changes in the size of the zone of orientation Δr_o and zone of attraction Δr_a . The areas denoted as (a–d), correspond to the area of parameter space in which the collective behaviours (A–D), respectively, are found. Area (e) corresponds to the region in parameter space, where groups have a greater than 50% chance of fragmenting. $N=100$, $r_r=1$, $\alpha=270$, $\theta=40$, $s=3$, $\sigma=0.05$. Data shown in (E) and (F) are the mean of 30 replicates per parameter combination.

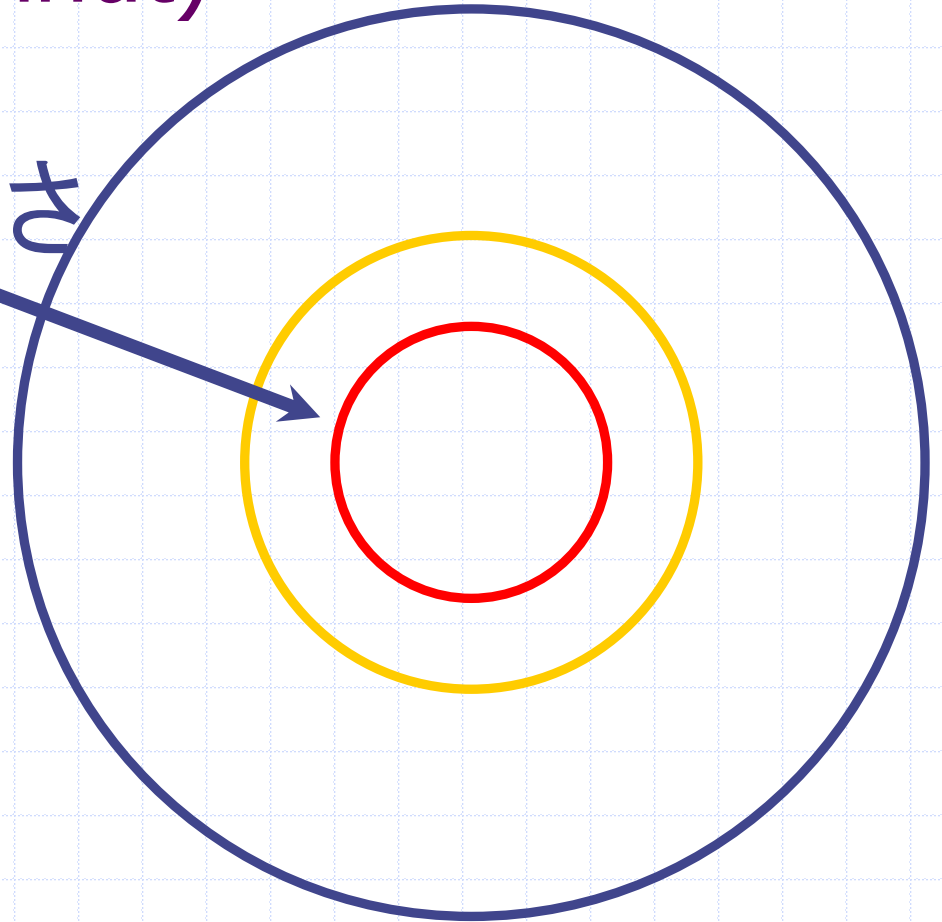
Swarming

Zooの領域が狭い



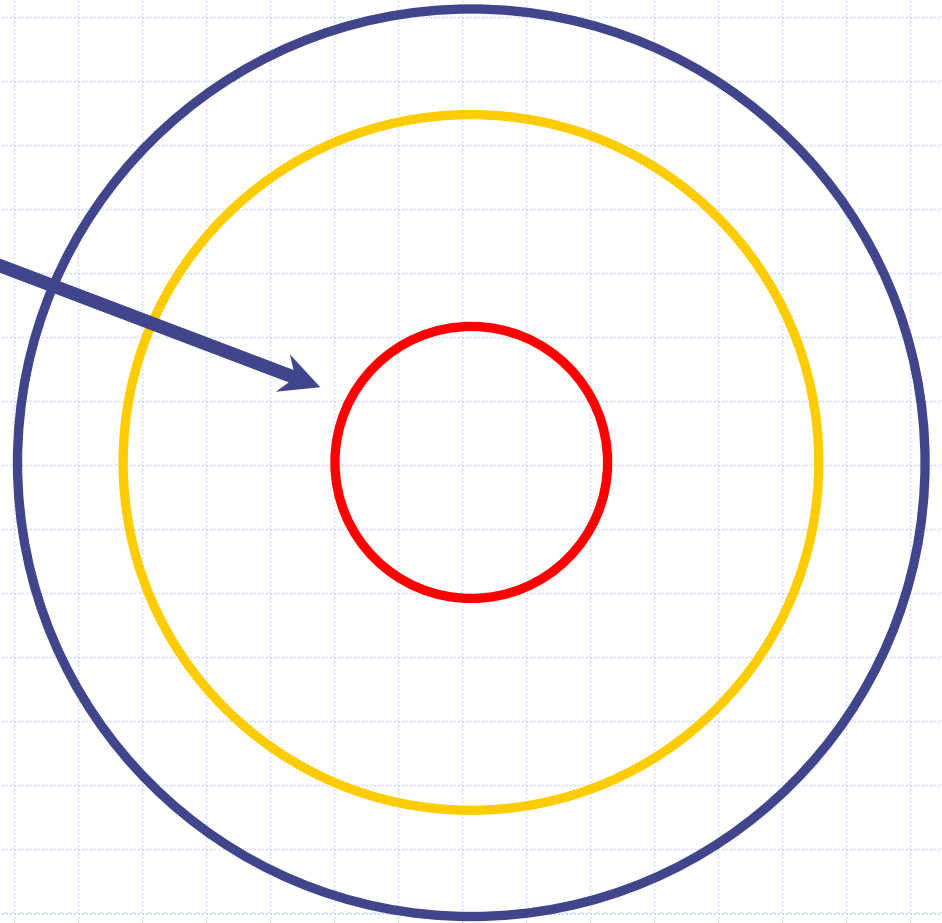
Torus (ring-doughnut)

Zooが中間の大きさ



Directed Shoal

Zooが大きな領域

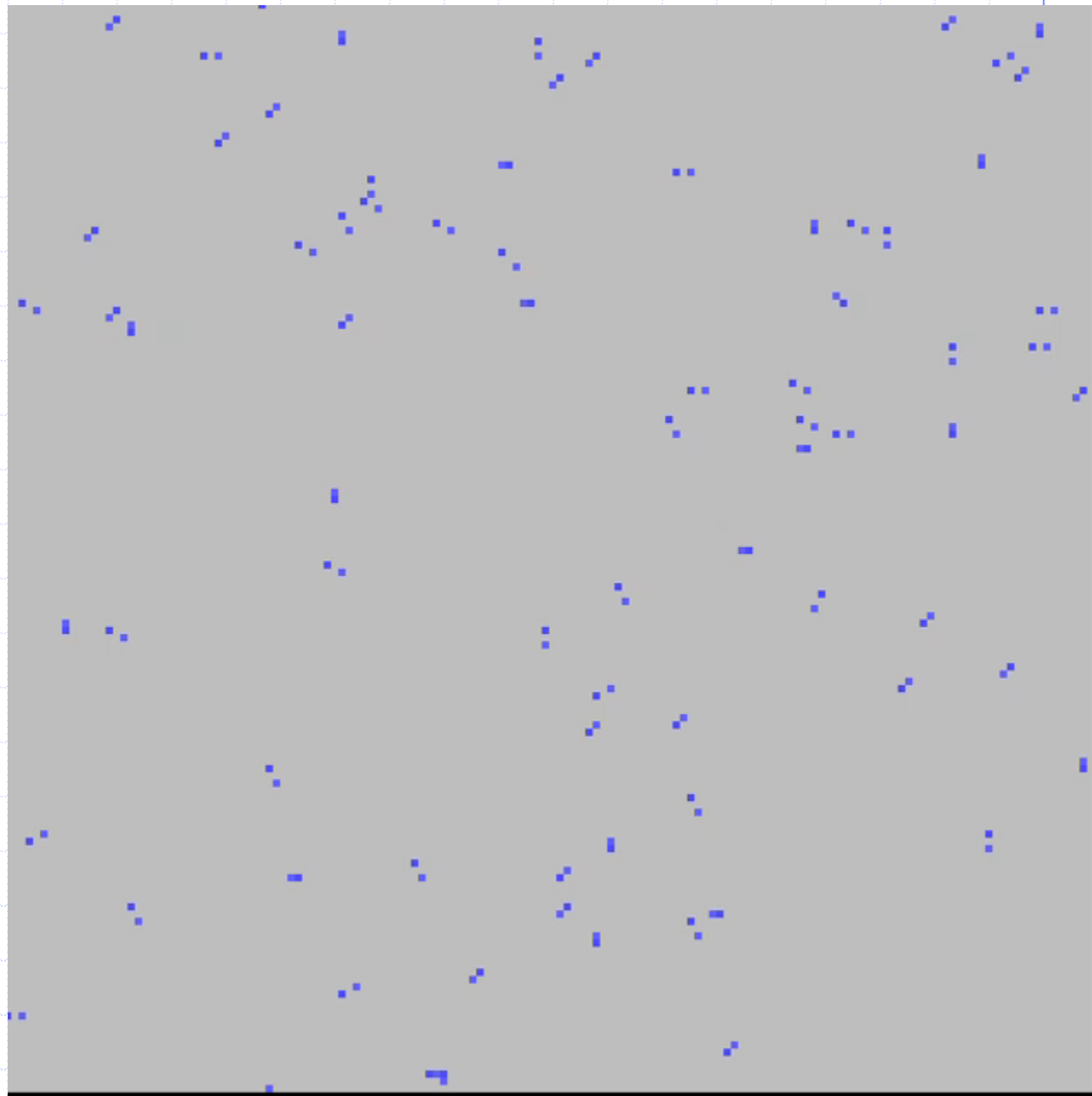


Swarming

7% Bu... — □ ×

BugCreator

bugType	2
moveType	2
bugDensity	0.004
bugNum	-1
defaultSpeed	1.6
minSpeed	1.2
maxSpeed	2.5
accel	1.025
gravityWeight	0.04
nearWeight	0.01
repulRadian	2
avoidRadian	16
orientRadian	3
searchRadian	32.7
searchAngle	270
stdRotate	0.02
maxRotate	5
maxRotateInAvoiding	5
trailingNum	5

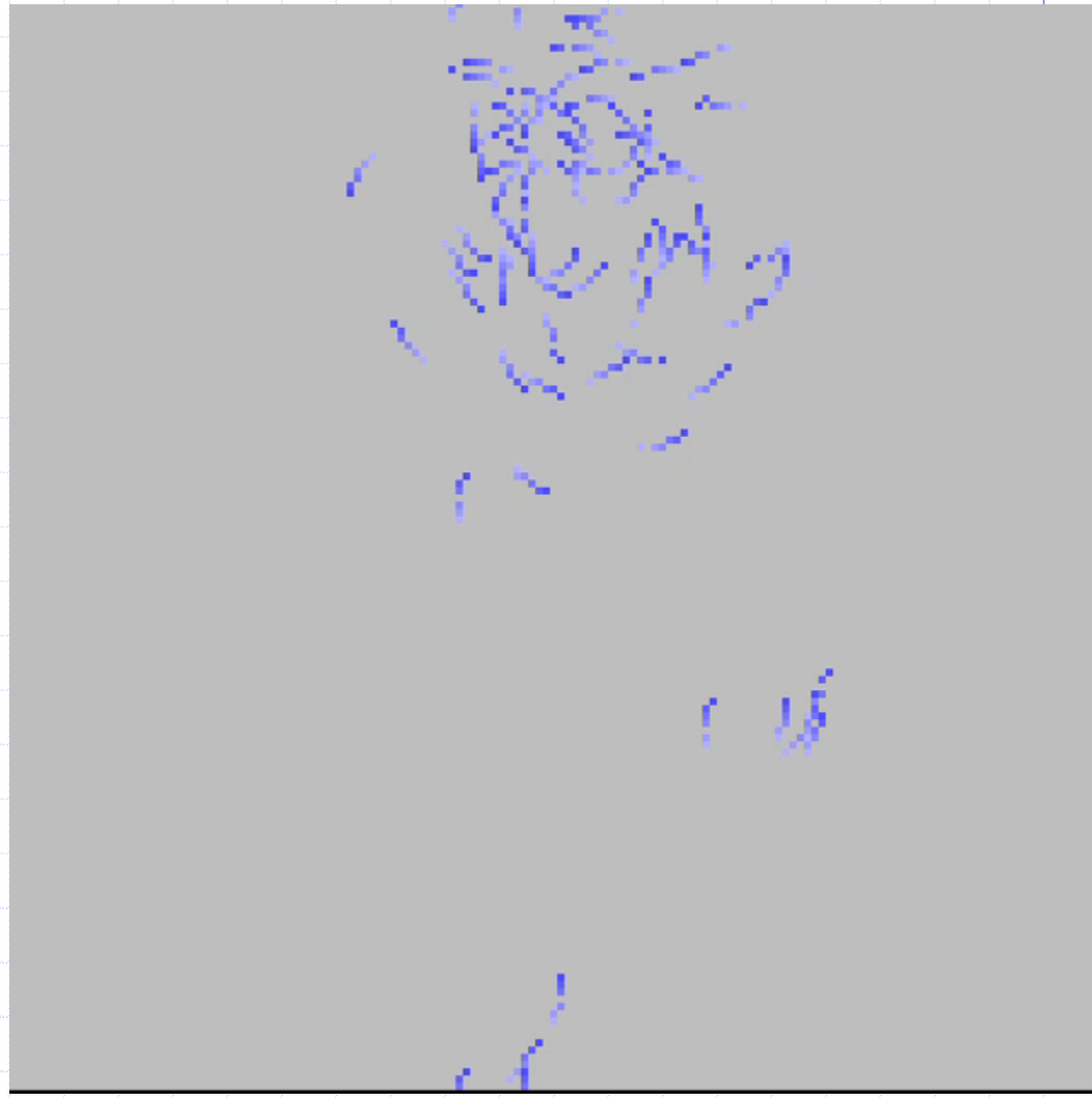


Torus

74 Bu... - □ ×

BugCreator

bugType	2
moveType	2
bugDensity	0.004
bugNum	-1
defaultSpeed	1.6
minSpeed	1.2
maxSpeed	2.5
accel	1.025
gravityWeight	0.04
nearWeight	0.01
repulRadian	2
avoidRadian	16
orientRadian	7
searchRadian	32.7
searchAngle	270
stdRotate	0.02
maxRotate	5
maxRotateInAvoiding	5
trailingNum	5

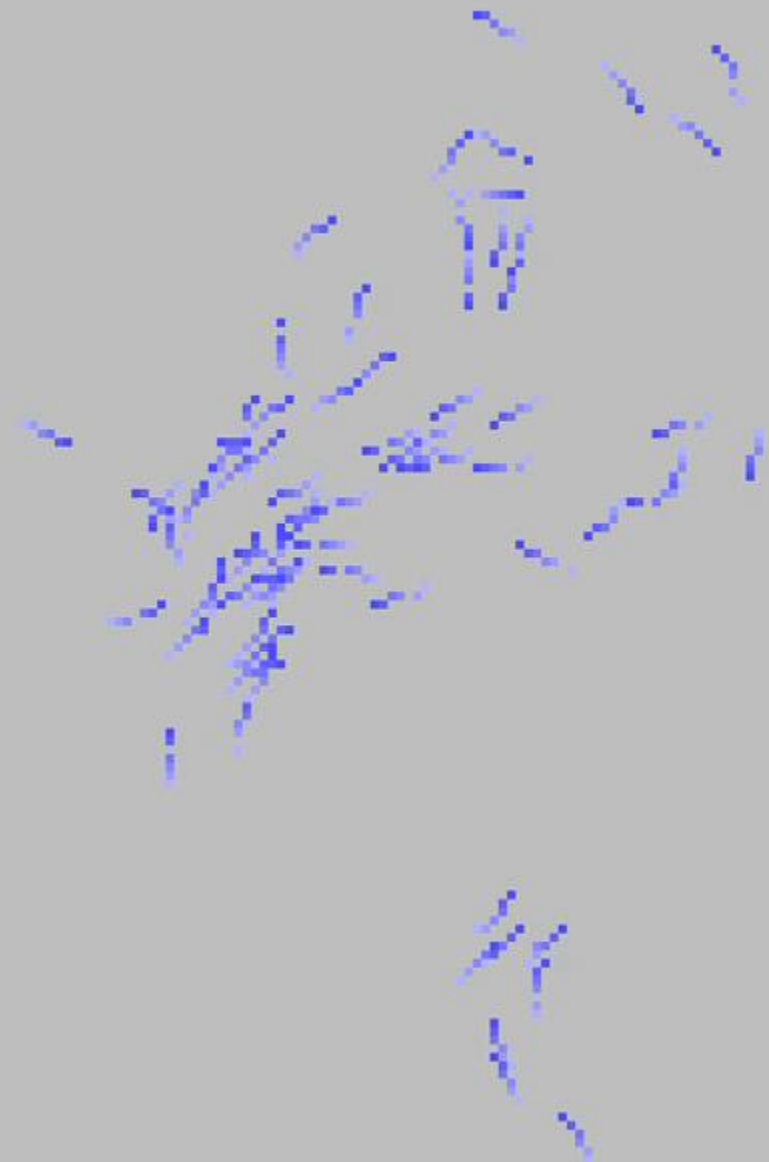


parallel

7% Bu... — □ ×

BugCreator

bugType	1
moveType	3
bugDensity	0
bugNum	1
defaultSpeed	2
minSpeed	1.5
maxSpeed	2
accel	1
gravityWeight	0.04
nearWeight	0.01
repulRadian	2
avoidRadian	30
orientRadian	10
searchRadian	32.7
searchAngle	360
stdRotate	0.02
maxRotate	2
maxRotateInAvoiding	2
trailingNum	5



鳥と魚の群れを制御しよう

- Swarm
- Parallel
- Torus

