GSC January@GSAS 2023 Mini-Course Introduction to Generative Art and Scientific Visualization Day 4: Tools for visualization

# Processing and Boids Flocking Simulation





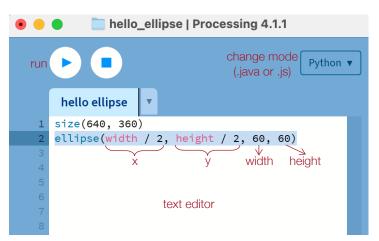


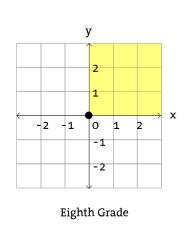


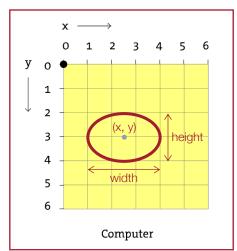


## What is Processing?

- Processing is a flexible software sketchbook and a language for learning how to code<sup>1</sup>:
  - promotes software literacy within the visual arts and visual literacy within technology;
  - ideal for quick prototyping and interactive design.



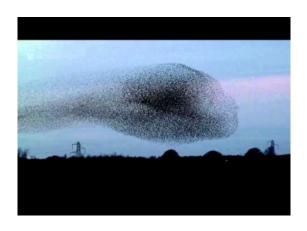




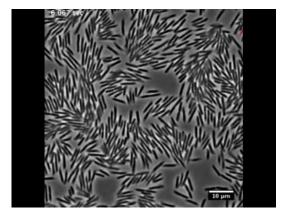
main Processing window

coordinate system in Processing<sup>2</sup>

### Flocking behavior in nature







flock of birds<sup>1</sup>

school of fish<sup>2</sup>

swarm of bacteria<sup>3</sup>

create an <u>interactive</u> code in <u>Processing</u> to simulate the flocking behaviors based on the <u>Boids</u> algorithm

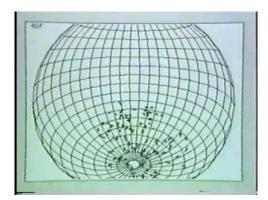
YouTube: "Gretna Green Starling Murmurations", https://youtu.be/M1Q-EbX6dsc

<sup>&</sup>lt;sup>2</sup> YouTube: "Sardine Feeding Frenzy with Sharks, Penguins and More | The Hunt | BBC Earth", https://youtu.be/6zOarcL1BSc <sup>3</sup> YouTube: "Motions of Swarming E coli Bacteria", https://youtu.be/q27Jn3h4kpE

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ARTICLES	CITED BY	CO-AUTHORS		
TITLE			CITED BY	YEAR
Flocks, herds and schools: A distributed behavioral model CW Reynolds Proceedings of the 14th annual conference on Computer graphics and			13532	1987

- Boids<sup>1</sup> is an artificial life program developed by Craig Reynolds to simulate flocking:
  - refers to simulated bird-like, "bird-oid" objects;
  - generically represents objects of polarized, noncolliding, aggregate motion, like school of fish;
  - has many applications/extensions in movies, also the scientific communities.



the original *Boids* program<sup>2</sup> (1986)



the bat swarming scene<sup>3</sup> in Batman Returns (1992)

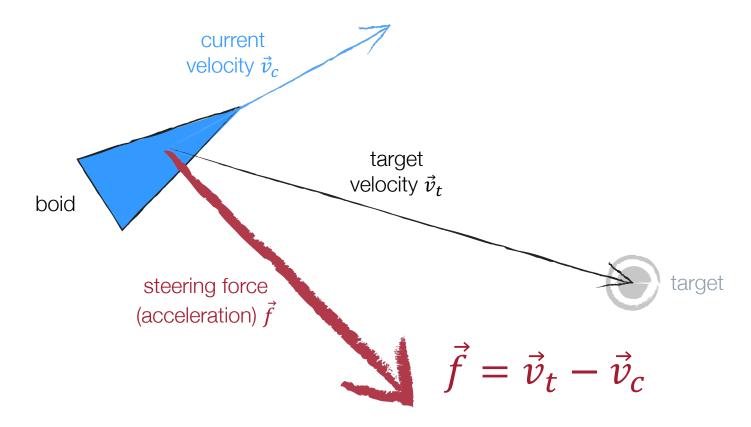


the stampede scene<sup>4</sup> in *The Lion King* (1994)

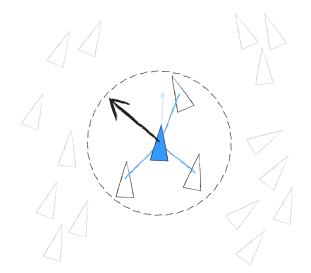
<sup>&</sup>lt;sup>1</sup> Boids (background and update) by Craig Reynolds: https://www.red3d.com/cwr/boids/ <sup>2</sup> YouTube: "Original 1986 Boids simulation", https://youtu.be/86iQiV3-3IA

 <sup>&</sup>lt;sup>3</sup> YouTube: "Flock of bats (Batman Returns 1992)", https://youtu.be/A8Xt3DlrwhY
 <sup>4</sup> YouTube: "Stampede (The Lion King 1994)", https://youtu.be/x\_EVWUT3A

#### Vector basics

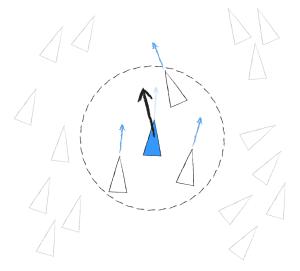


## Three (basic) flocking rules<sup>1</sup>



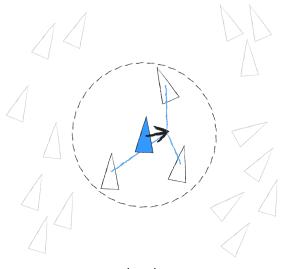
separation

steer to avoid colliding with local flockmates



alignment

steer towards the average direction of local flockmates



cohesion

steer towards the average position of local flockmates

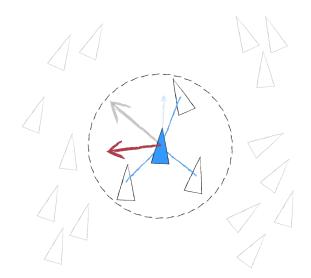
## Three (basic) flocking rules<sup>1</sup>

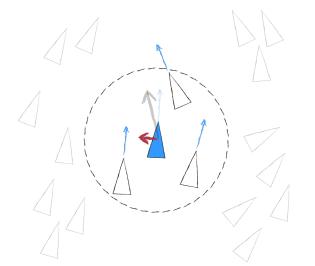
 $\vec{x}_i$ : position of current boid  $\vec{v}_i$ : velocity of current boid

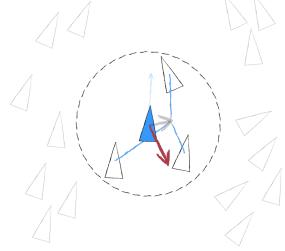
 $\vec{x}_j$ : position of flockmates  $\vec{v}_i$ : velocity of flockmates

 $v_m$ : maximum speed

 $f_m$ : maximum force magnitude







separation
$$\frac{\vec{f}_s}{m} = \left(\frac{1}{n-1} \sum_{i \neq j}^{n-1} \frac{1}{\left\|\vec{x}_i - \vec{x}_j\right\|} \cdot \frac{\vec{x}_i - \vec{x}_j}{\left\|\vec{x}_i - \vec{x}_j\right\|}\right) - \vec{v}_i$$
weighted velocity
by distance direction

alignment 
$$\frac{\vec{f_a}}{m} = \left(\frac{1}{n-1} \sum_{i \neq j}^{n-1} \vec{v_j}\right) - \vec{v_i}$$
 average velocity

cohesion 
$$\frac{\vec{f_c}}{m} = \left(\frac{1}{n-1} \sum_{i \neq j}^{n-1} \vec{x_j}\right) - \vec{x_i} - \vec{v}$$
 average position