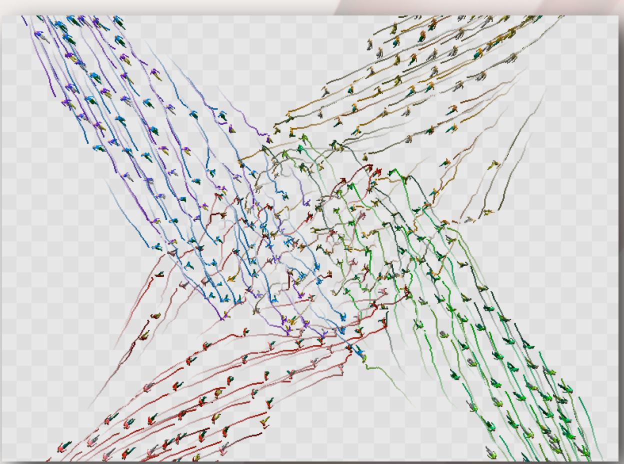
# Crowds and Flocks

**Adrien Treuille**

# What this is about...

- not human / animal motion.

- ...but group motion paths.



# Previous Questions

- What are the relevant properties of crowds?
- Can crowds be modeled as particles?
- How?
- What phenomena does your algorithm capture, what doesn't it?

# Student Answers

- properties
    - # of people / density
    - target goal
        - or _negative_ goals
        - or _multiple_ goals (with different people)
    - crowd has a "dominant direction"
        - but _some_ individuals might not follow it
        - _alignment_ force that pushes people in the dominant direction
    - environment
    - noisiness / smelliness
    - _mingling_
        - not all people are GOING SOMEWHERE (let's face it)
- individual don't want to collide
    - using particles + collision "force"
    - force that repels particles
- how to achieve density
    - cohesion force
- proximity awareness
    - field of view of each particle (what they can see)
- model with a density field instead of particles
- people can't instantaneously change directions
    - model people as rigid bodies

# Overview

- Flocking
- Crowds
- Applications
- Current Challenges
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# Which is Real?

**Source: http://massivesoftware.com/**

# Real Flocking and Schooling

- No upper bound on size:
  - 17 mile schools of Herring with millions of fish.
  - => Localized reasoning.
- Collision Avoiance
- Centering
  - Protection from predators.
  - Social Advantages
  - Better search.

# Boid Model - I

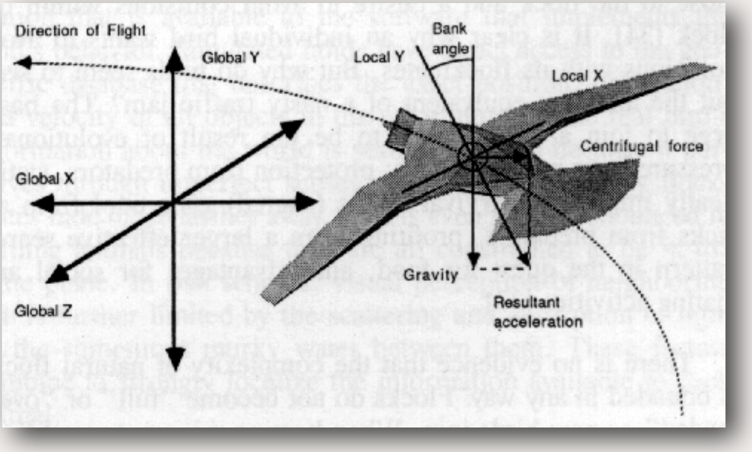
- Craig Reynolds 1987
- Simple local rules lead to compelling flocking behavior.

# Boid Model - II

- **Boid Particle:**

$$\frac{d}{dt}\begin{bmatrix} x \\ \dot{x} \end{bmatrix} = \begin{bmatrix} \dot{x} \\ f \end{bmatrix}$$

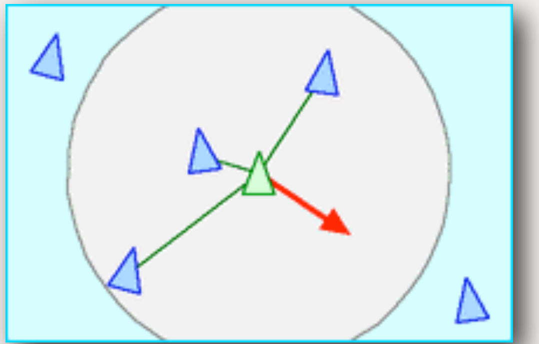
- **Forces:**
  - **Dynamical forces:**




  - **Ordered set of "flocking forces"**

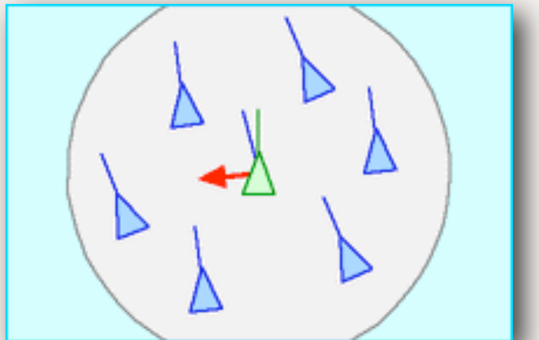
**Source: Reynolds. 1987**

# Boid Model - III



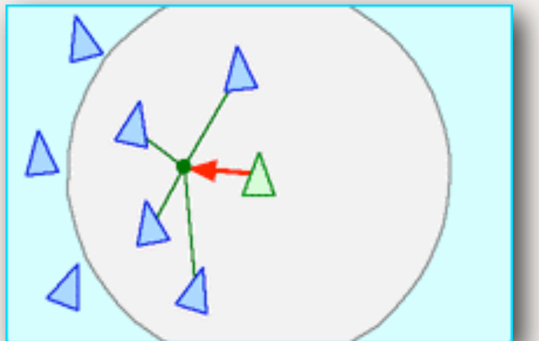
## Separation

Steer to avoid crowding local flockmates



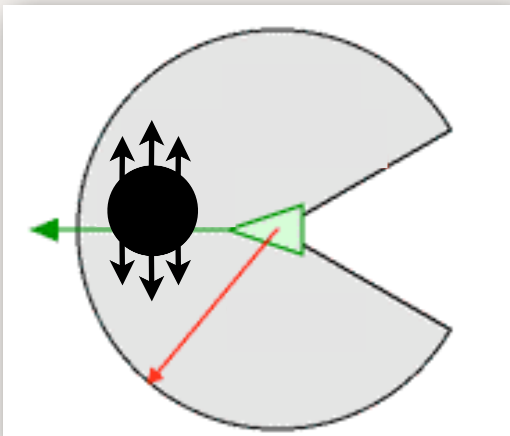
## Alignment

Steer towards the average heading of local flockmates



## Cohesion

Steer to move toward the average position of local flockmates

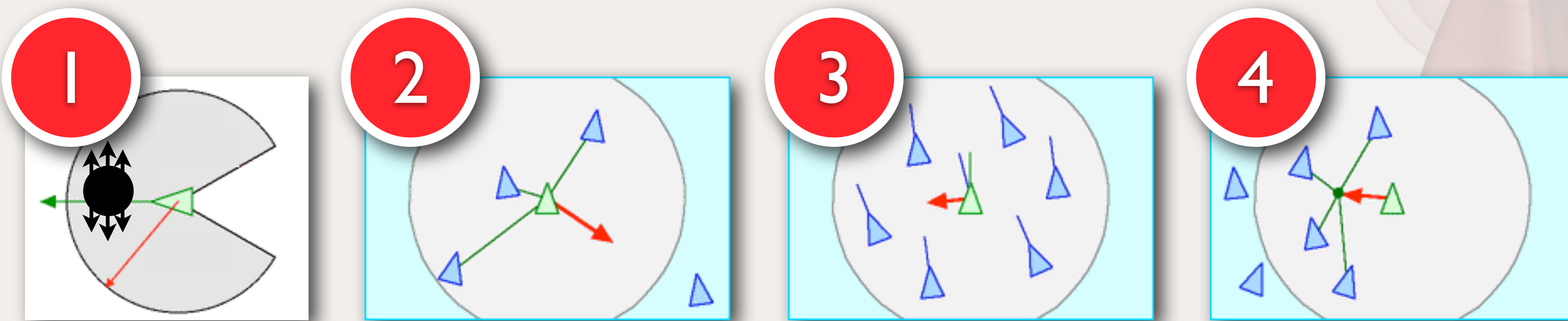


## Obstacle Avoidance

Move towads the gradient of obstacles.

# Boid Model - IV

- How to combine forces?




Avoidance Separation Alignment Cohesion

- Force ordering scheme.

# Making of Honda Video

**Source: http://massivesoftware.com/**

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# Crowds

**Source: http://massivesoftware.com/**

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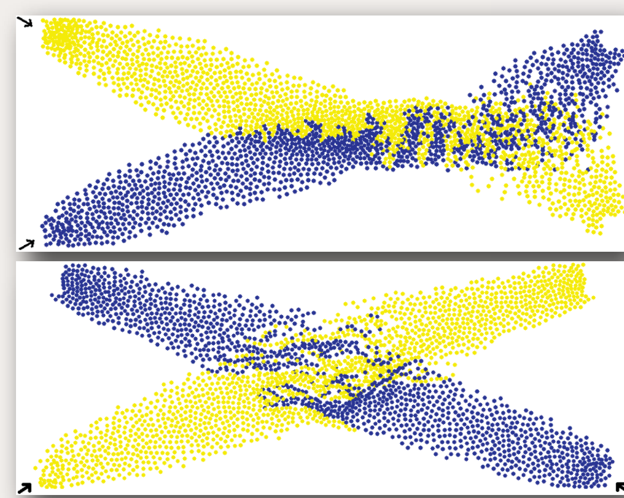
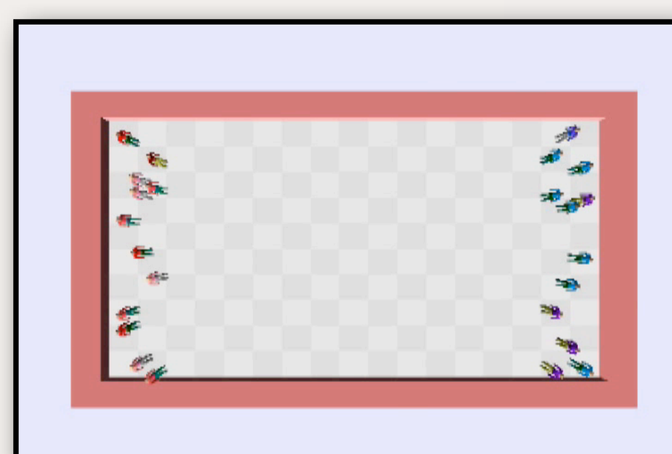
# Properties of Real Crowds

- Goal Directed
- Obstacle / Collision Avoidance
- Striping



Source: Helbing et. al. 2005

- Lane Formation



# Social Forces Model

- **At walking speed, humans do not act like Newtonian particles.**
- **Can change speed and direction (almost) instantly.**
  - **Consequently the second-order force model is incorrect.**

$$\frac{d\mathbf{x}}{dt} = \sum_{i=1}^{N} \alpha_i \mathbf{f}_i$$

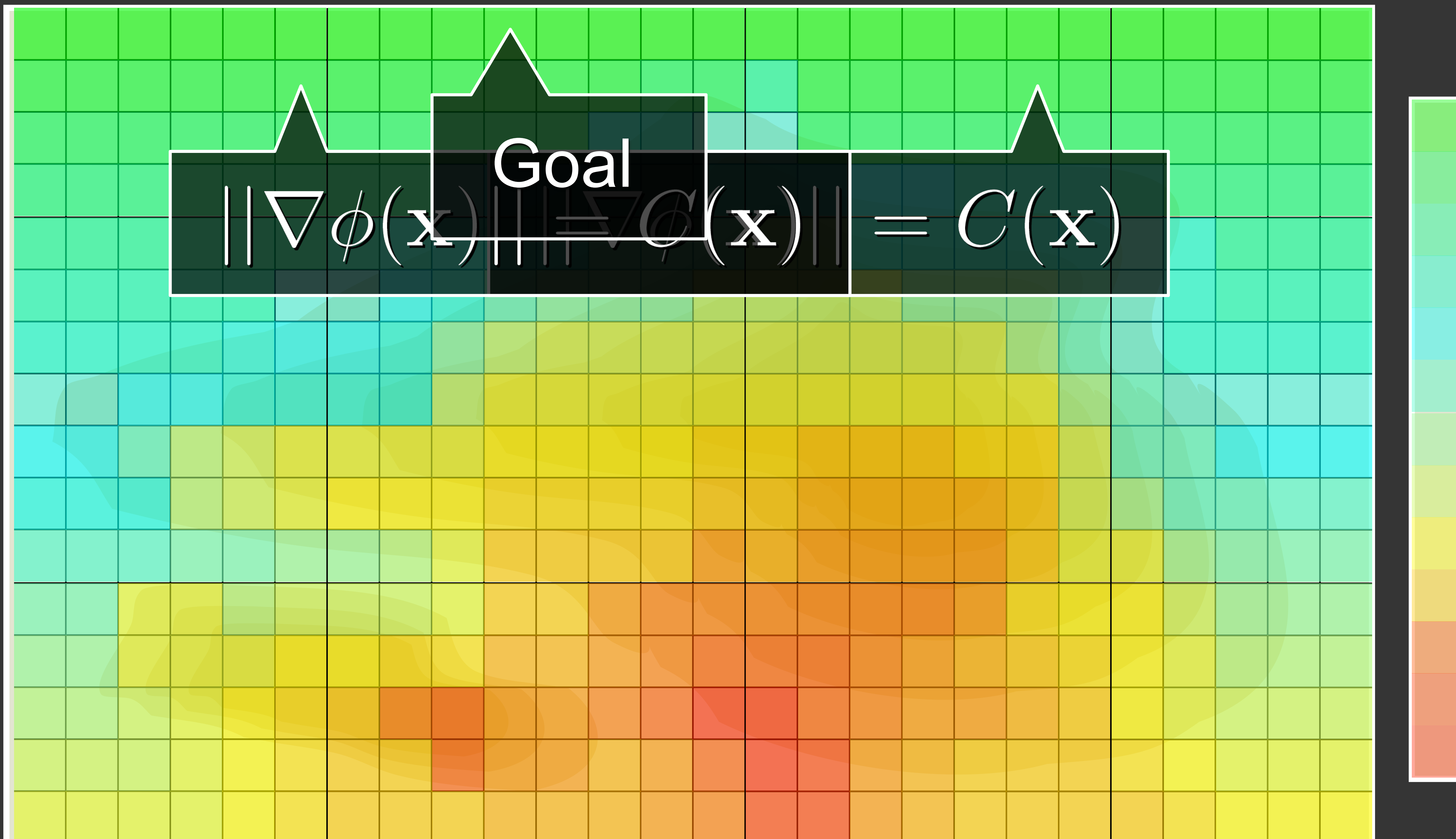
- **The $f_i$s are called *social forces*.**

# Steering Forces

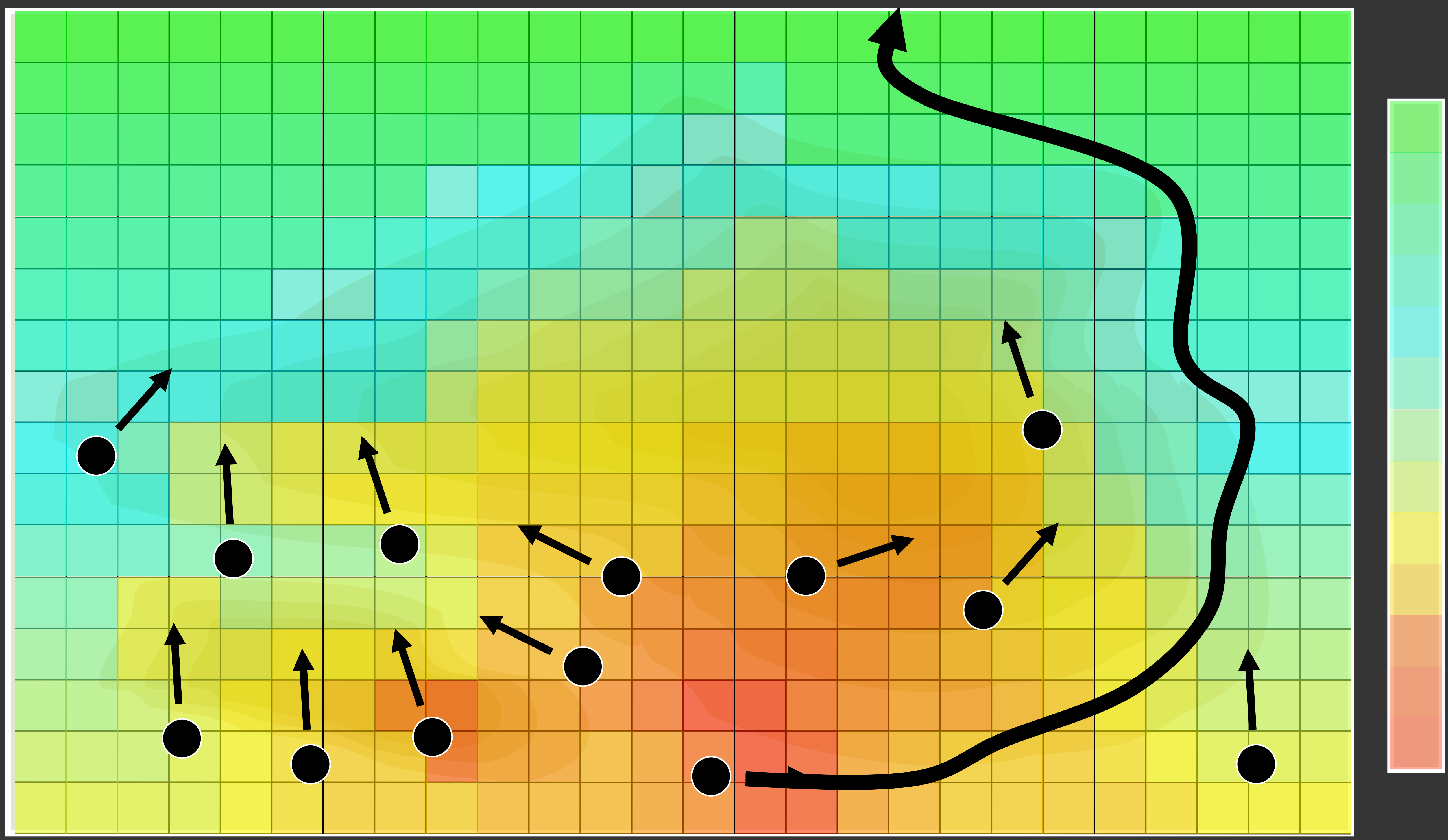
$$\mathbf{f}(\mathbf{x}) = \frac{\mathbf{x} - \hat{\mathbf{x}}}{||\mathbf{x} - \hat{\mathbf{x}}||}$$

**Where does $\hat{\mathbf{x}}$ come from?**

# Potential

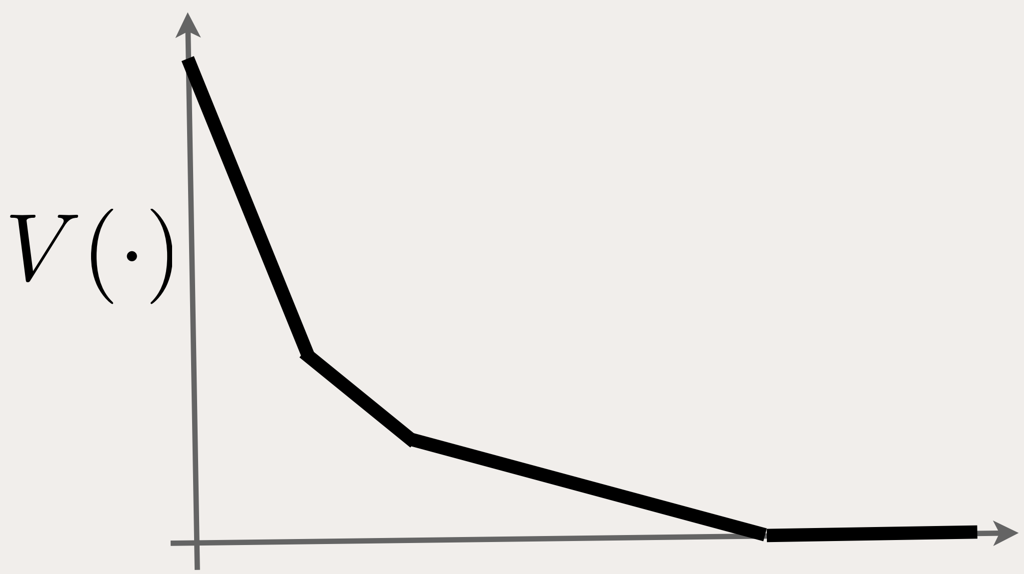


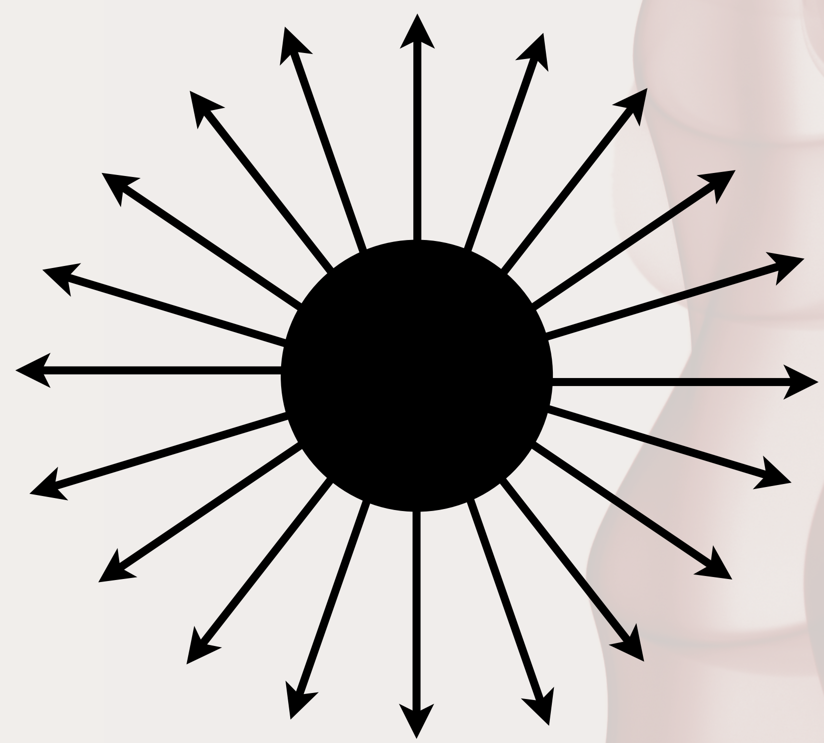
# Potential



# Obstacle Avoidance

$$\mathbf{f}(\mathbf{x}) = -\nabla V(||\mathbf{x} - \mathbf{b}||)$$



# Pedestrian Avoidance

$$f(\mathbf{x}_a, \mathbf{x}_b) = e^{\frac{\mathbf{x}_a - \mathbf{x}_b}{B}} \left( \lambda + (1 - \lambda) \frac{1 + \cos(\phi_{a,b})}{2} \right)$$

# Crowds

**Source: http://massivesoftware.com/**

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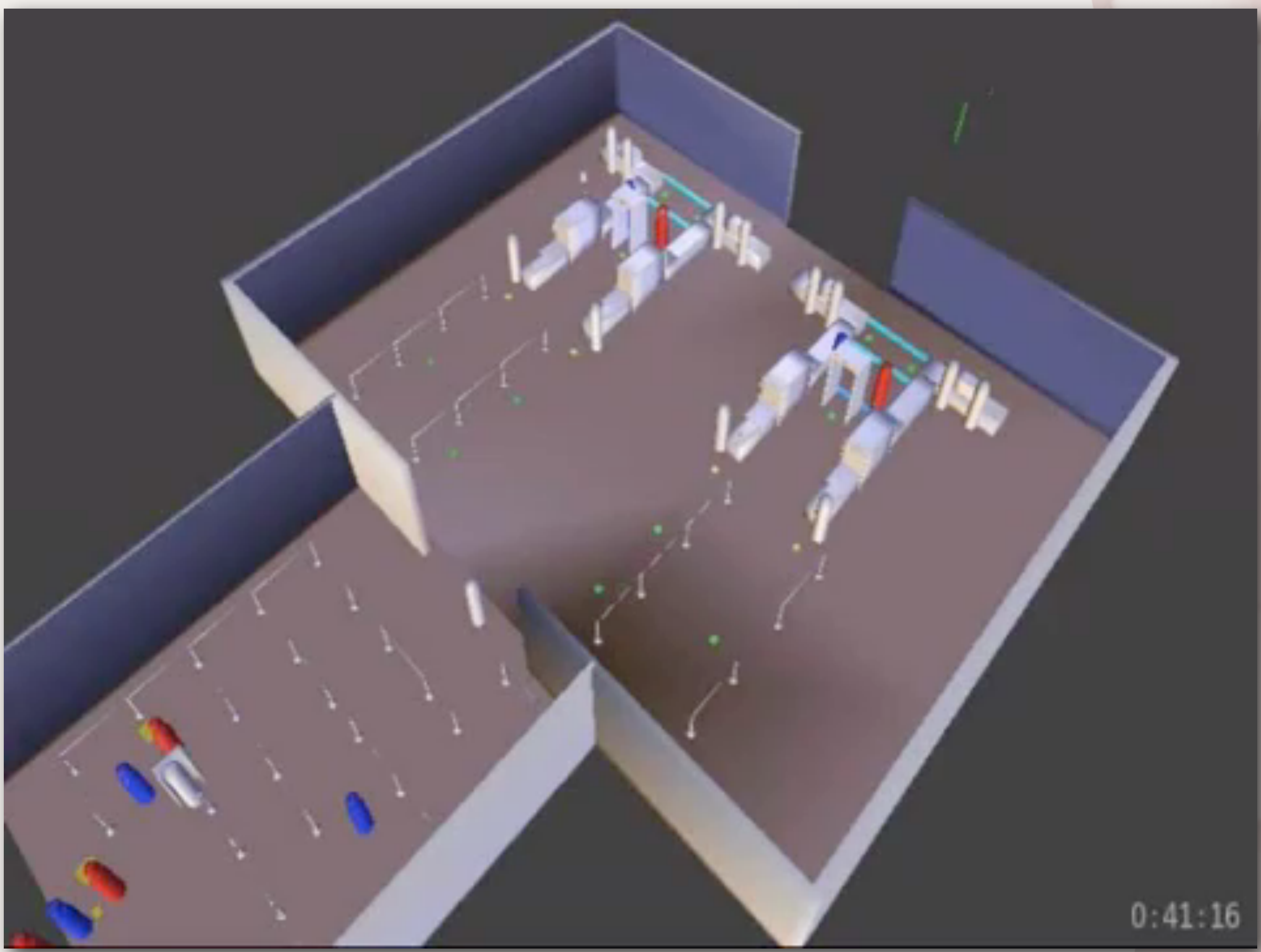
# Emergency Planning

**Source: http://massivesoftware.com/**

# Urban Design




**Source: http://massivesoftware.com/**

# Architecture Visualization

Source: http://massivesoftware.com/

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# Current Challenges

- High density crowds.
- Motion paths aren’t enough.
  - Talk with other people.
  - Tie their shoes.
- Connection with human motion model.
- Computational Advantage of Crowd Cohesion

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# Question

- What are the relevant properties of fluids such as water and smoke?
  - How do smoke, water, fire, and explosions differ?
- Can you propose mathematical properties / functions that capture these properties?
- How can these be simulated?
- What phenomena does your algorithm capture, what doesn't it?

# Student Answers

# Student Answers

- “types” of fluids
    - gaseous fluids
    - liquid forces
    - explosions
        - like ink in water -- but diffuses out from a point
    - should we handle these differnetly?
- forces
    - separation
    - cohesion
    - gravity
- properties
    - density
    - temperature
    - viscosity
- different fluids mixing-- how to handle this
    - water + air
    - oil + water
- how to model
    - on a “grid”
        - represent the pressure difference between air and water
    - particles with springs