Flow Fields

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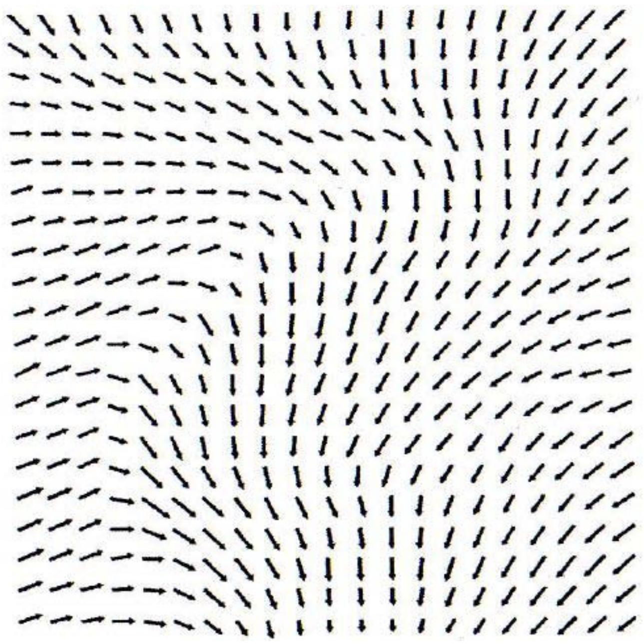
Motivation for Flow Fields

- Multiple AI algorithms in a computer game can produce conflicting results. The AI must resolve these conflicts and find a simultaneous solution.

Example Flowfield



- Simple definition: A flow field is a grid of vectors.
- If you are here, go this way.
- Or: one influence on your motion is captured in this flow field, e.g., magnetic attraction.

Flow Field

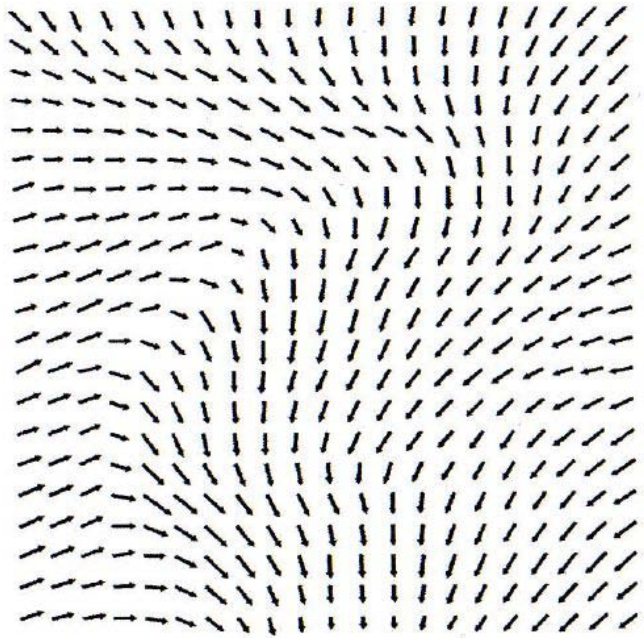
- “A flow field consists of a three-dimensional sample space that returns a vector at every point, indicating an attraction toward objects of interest or repulsion away from objects to be avoided” [Alexander, 2006].
- We will concentrate on two-dimensional flow fields.

A flow field has two components:

- A static data set constructed around static objects (e.g. terrain)
- A dynamically generated data set constructed around dynamic objects (e.g. vehicles)

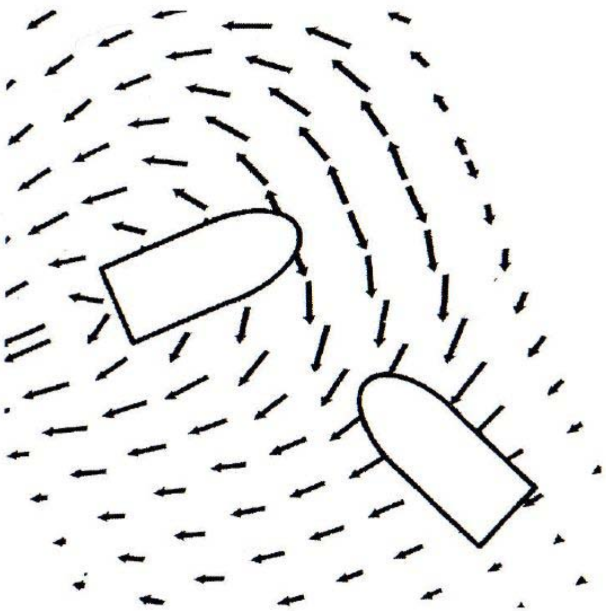
Static Fields

- “A static field is time-invariant: it will always return the same output vector for any given input vector” [Alexander 2006].
- We can use it as a function: we give it an (x, y) vector representing a position and it returns an (x, y) vector representing a velocity.



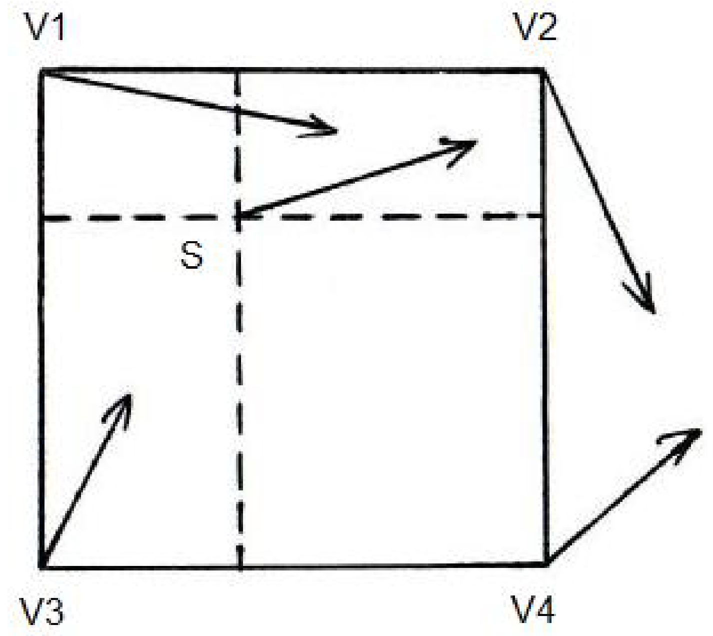
Dynamic Fields

- “A dynamic field can vary with time to produce different output vectors for a given input vector” [Alexander 2006].
- It is usually controlled by parameters other than the input vector.



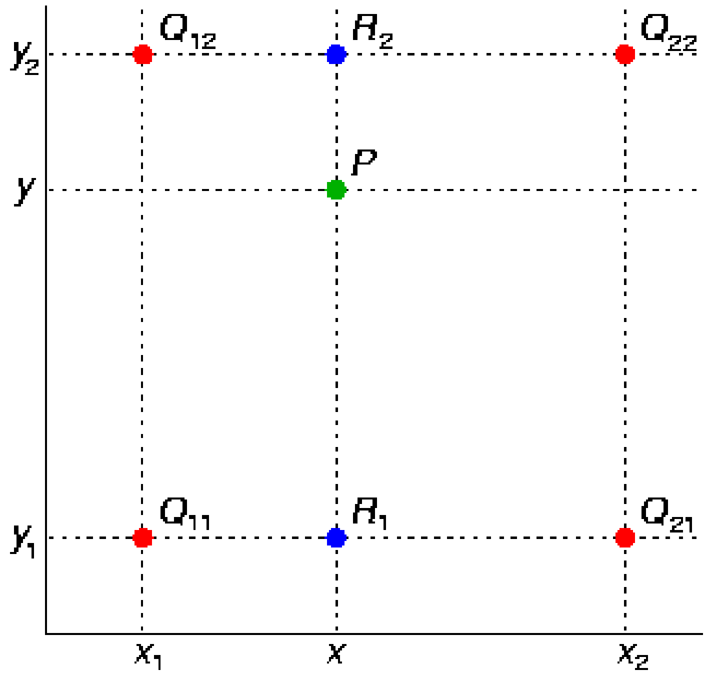
Representing Flow Fields

- Storing the Field
  - Use a grid to store the data (vectors) that represent the state of the flow field
- Sampling the Field
  - Interpolate values between data points



Bilinear Interpolation

- Bilinear interpolation interpolates a function of two variables, defined at grid points, to the continuous space between.



- Suppose the function's values is defined at grid points $Q_{11} = (x_1, y_1)$, Q_{12}, Q_{21}, and Q_{22}.
- We want to find the value at point $P = (x, y)$.

Step 1: linear interpolation in the x-direction

$$f(R_1) \approx \frac{x_2 - x}{x_2 - x_1} f(Q_{11}) + \frac{x - x_1}{x_2 - x_1} f(Q_{21}) \quad \text{where} \quad R_1 = (x, y_1),$$

$$f(R_2) \approx \frac{x_2 - x}{x_2 - x_1} f(Q_{12}) + \frac{x - x_1}{x_2 - x_1} f(Q_{22}) \quad \text{where} \quad R_2 = (x, y_2).$$

Step 2: interpolating in the y-direction

$$f(P) \approx \frac{y_2 - y}{y_2 - y_1} f(R_1) + \frac{y - y_1}{y_2 - y_1} f(R_2).$$

This gives us the desired estimate of f(x, y)

$$\begin{aligned} f(x,y) \approx & \frac{f(Q_{11})}{(x_2 - x_1)(y_2 - y_1)} (x_2 - x)(y_2 - y) \\ & + \frac{f(Q_{21})}{(x_2 - x_1)(y_2 - y_1)} (x - x_1)(y_2 - y) \\ & + \frac{f(Q_{12})}{(x_2 - x_1)(y_2 - y_1)} (x_2 - x)(y - y_1) \\ & + \frac{f(Q_{22})}{(x_2 - x_1)(y_2 - y_1)} (x - x_1)(y - y_1). \end{aligned}$$

Combining Fields

- Weighted Addition (+)

  Take all of the component fields into account and provide the ability to prioritize some fields.

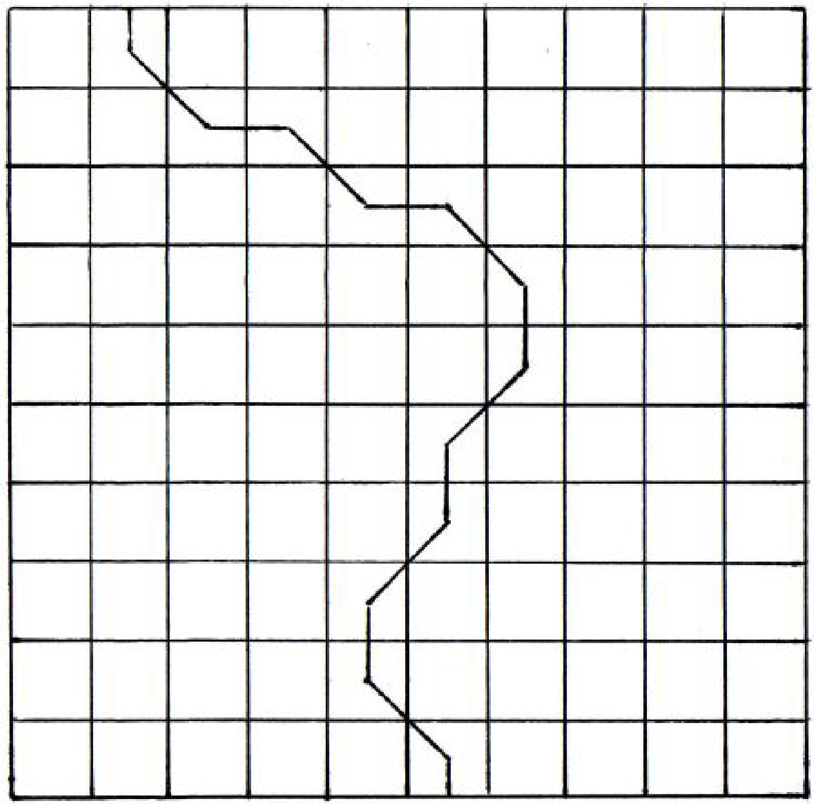
- Conditional Operation (OR)

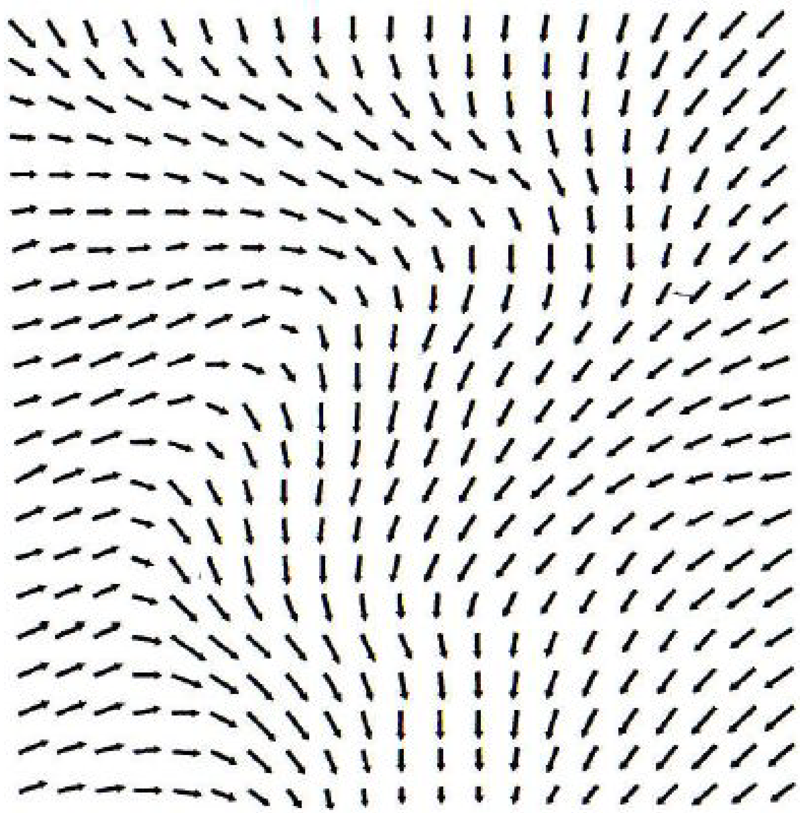
  Allow one field to completely override other fields.

- Field Multiplication (*)

  Scaling value for each point in the field is the result of sampling another field. (Scaling or dot product)

Example 1: A* Smoothing

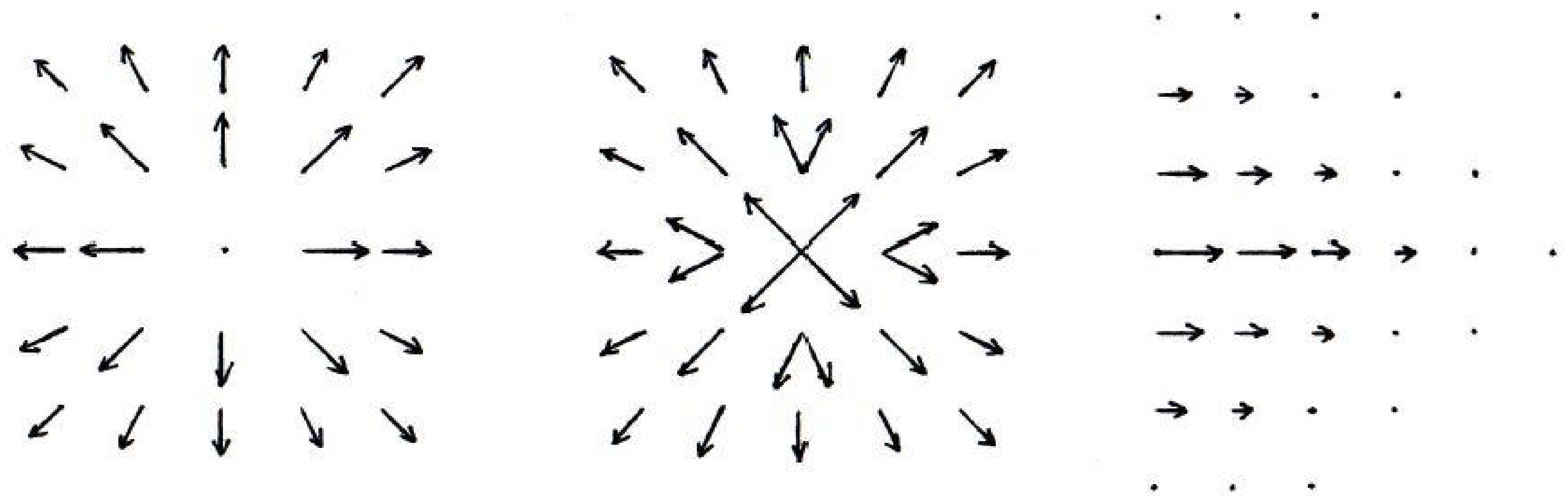




- Use flow field to create a smooth path

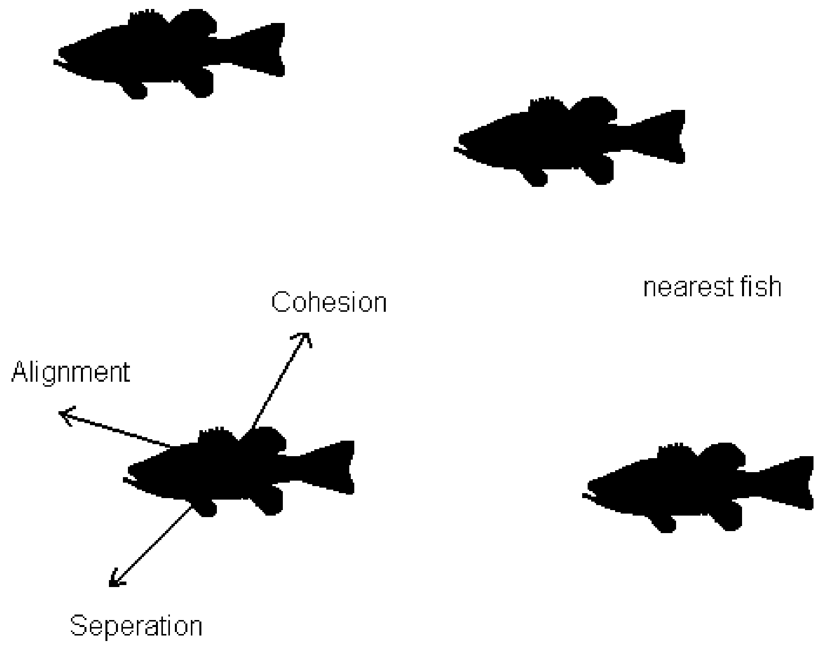
Example 2: Collision Avoidance

- Dynamic Object Avoidance
  1. Non-mirrored radial repulsion field – has dead zone at center
  2. Mirrored radial repulsion field – avoids dead zone
  3. Sideways repulsion



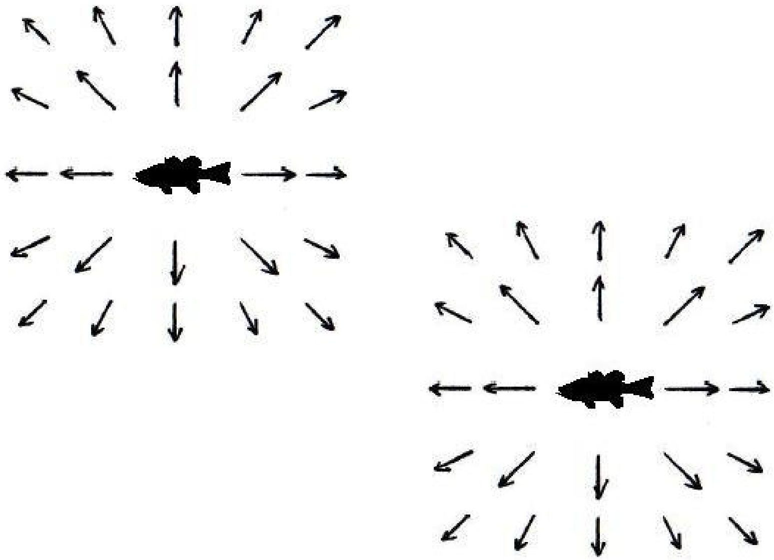
Flocking

- Reynolds's boids
  - **Separation**: steer to avoid crowding nearby fish (provides collision avoidance).
  - **Alignment**: steer towards the average heading of nearby fish (helps keep school together).
  - **Cohesion**: steer to move toward the average position of nearby members (helps flock centering).



Flocking System with Flow Field

- Generate a local dynamic flow field around each fish according to their movement.
- Combine all local fields together before adjusting fish's movement.



Sources of Flow Fields

- Visualization and editing tools can be used to create flow fields.
- Convert from a 2-D sample to a 3-D sample.
- Brushes can be used to create a good flow field.

Conclusion

- Flow fields provide elegant solutions to a wide variety of problems.
- They greatly reduce problems such as oscillation by representing smooth flow rather than giving different results at nearby samples.