

Boids!

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What are Boids?

- ▶ An artificial life simulation [2, 6]
- ▶ 'Bird-oid' flocking behaviour [2, 6]
- ▶ First described by Craig Reynolds in 1987 [6]

Why Boids?

- ▶ Some major appearances:
 - ▶ *Half-Life* (1998)
 - ▶ *Batman Returns* (1992)
- ▶ Other applications:
 - ▶ Swarm optimization [1]
 - ▶ Unmanned vehicle guidance [7, 5]

Our Implementation

- ▶ **Simulation:** Boids in a toroidal 2D space
- ▶ **Haskell** programming language:
 - ▶ A strongly-typed, lazy, purely functional programming language
 - ▶ Why Haskell?
 - ▶ Good for rapid prototyping [3]
 - ▶ Modularity [4]
 - ▶ Prior experience
 - ▶ Explore non-OO ways of representing agents

What is a Boid?

- ▶ A boid consists of:
 - ▶ A position p_i
 - ▶ A velocity vector \vec{v}_i
 - ▶ A sight radius r

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- ▶ In Haskell:

```
type Vector = V2 Float
```

```
type Point  = V2 Float
```

```
type Radius = Float
```

```
data Boid = Boid { position :: !Point  
                  , velocity :: !Vector  
                  , radius   :: !Radius  
                  }
```

```
deriving (Show)
```

Boid Behaviour

- First, we define some types:

```
type Update      = Boid -> Boid
```

```
type Perception = [Boid]
```

```
type Behaviour  = Perception -> Update
```

Boid Behaviour

- First, we define some types:

```
type Update      = Boid -> Boid
type Perception  = [Boid]
type Behaviour   = Perception -> Update
```

- Functions for finding a boid's neighborhood:

```
inCircle :: Point -> Radius -> Point -> Bool
inCircle p_0 r p_i = ((x_i - x)^n + (y_i - y)^n) <= r^n
  where x_i = p_i ^.x
        y_i = p_i ^.y
        x   = p_0 ^.x
        y   = p_0 ^.y
        n   = 2 :: Integer
```

```
neighborhood :: World -> Boid -> Perception
neighborhood world self =
  filter (inCircle cent rad . position) world
  where cent = position self
        rad  = radius self
```


Separation steering vector

- ▶ Tendency to avoid collisions with other boids

$$\vec{s}_i = - \sum_{\forall b_j \in V_i} (p_i - p_j)$$

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- In Haskell:

```
separation :: Boid -> Perception -> Vector
separation self neighbors =
    let p = position self
    in negated $
        sumV $ map (^-^ p) $ positions neighbors
```

Cohesion steering vector

- ▶ Tendency to steer towards the centre of visible boids
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Cohesion steering vector

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- ▶ **Step I:** Find the centre:

$$c_i = \sum_{\forall b_j \in V_i} \frac{p_j}{m}$$

- ▶ In Haskell:

```
centre :: Perception -> Vector
centre boids =
    let m = fromIntegral $ length boids :: Float
    in sumV (positions boids) ^/ m
```

Cohesion steering vector

- ▶ Tendency to steer towards the centre of visible boids
- ▶ Calculated in two steps.
- ▶ **Step II:** Find the cohesion vector:

$$\vec{k}_i = c_i - p_i$$

Cohesion steering vector

- ▶ Tendency to steer towards the centre of visible boids
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- ▶ **Step II:** Find the cohesion vector:

$$\vec{k}_i = c_i - p_i$$

- ▶ In Haskell:

```
cohesion :: Boid -> Perception -> Vector
cohesion self neighbors =
    let p = position self
    in centre neighbors ^~ p
```

Alignment steering vector

- Tendency to match velocity with visible boids

$$\vec{m}_i = \sum_{\forall b_j \in V_i} \frac{\vec{v}_j}{m}$$

Alignment steering vector

- Tendency to match velocity with visible boids

$$\vec{m}_i = \sum_{\forall b_j \in V_i} \frac{\vec{v}_j}{m}$$

- In Haskell:

```
alignment :: Boid -> Perception -> Vector
           -- :: Boid -> [Boid]      -> V2 Float
alignment _ [] = V2 0 0
alignment _ neighbors =
    let m = fromIntegral $ length neighbors :: Float
    in (sumV $ map velocity neighbors) ^/ m
```

Simulating a boid

1. Velocity update

$$\vec{v}_i' = \vec{v}_i + S.\vec{s}_i + K.\vec{k}_i + M.\vec{m}_i$$

Where S , K , and $M \in [0, 1]$

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1. Velocity update

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Where S , K , and $M \in [0, 1]$

2. Position update

$$p_i' = p_i + \Delta t \vec{v}_i$$

Simulating a boid

- In Haskell:

```
steer :: Weights -> Behaviour
```

```
steer (s, c, m) neighbors self =
```

```
    let s_i  = s *^ separation self neighbors
```

```
        c_i  = c *^ cohesion self neighbors
```

```
        m_i  = m *^ alignment self neighbors
```

```
        v'   = velocity self ^+^ s_i ^+^ c_i ^+^ m_i
```

```
        p    = position self
```

```
        p'   = p ^+^ v'
```

```
    in self { position = p', velocity = v'}
```

A brief demonstration

References



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