Boids!

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What are Boids?

- An artificial life simulation [1, 4]
- ‘Bird-oid’ flocking behaviour [1, 4]
- First described by Craig Reynolds in 1987 [4]

Why Boids?

- Some major appearances:
  - *Half-Life* (1998)
  - *Batman Returns* (1992)
- Other applications:
  - Swarm optimization
  - Unmanned vehicle guidance

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 [2]
    - Modularity [3]
    - Prior experience
    - Explore non-OO ways of representing agents

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- 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
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- 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

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- **Step I**: Find the centre:

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- In Haskell:

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

Cohesion steering vector

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- **Step II**: Find the cohesion vector:

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- 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

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

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- Tendency to match velocity with visible boids

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- 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

$$\vec{v_i\prime} = \vec{v_i} + S.\vec{s_i} + K.\vec{k_i} + M.\vec{m_i}$$

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

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

2. Position update

$$p\prime_i = p_i + \Delta t \vec{v_i}$$

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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