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

Haskell

- **Strong, Static Typing**: Compiler errors if types don't match
- **Lazy Evaluation**: Don't compute until asked to
- **Purely Functional**: Functions are first-class, no side effects

```haskell
foo :: Int -> [Int]
foo n = take n $ map (*2) [1..]

map :: (a -> b) -> [a] -> [b]
map _ []     = []
map f (x:xs) = f x : map f xs
```

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  = Speed -> 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
        -- :: Boid -> [Boid]     -> V2 Float
separation self neighbors =
    let p = position self
    in negated $
         sumV $ map (^-^ p) $ positions neighbors
```

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- In Haskell:

```
centre :: Perception -> Vector
    -- :: [Boid]      -> V2 Float
centre boids =
    let m = fromIntegral $ length boids :: Float
    in sumV (positions boids) ^/ m
```

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

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- In Haskell:

```haskell
cohesion :: Boid -> Perception -> Vector
      -- :: Boid -> [Boid]      -> V2 Float
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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- 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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2. Position update

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

Simulating a boid

- In Haskell:

```
steer :: Weights -> Behaviour
    -- :: Weights -> [Boid] -> Boid -> Boid
steer (s, k, m) speed neighbors self =
    let s_i  = s *^ separation self neighbors
        k_i  = k *^ cohesion self neighbors
        m_i  = m *^ alignment self neighbors
        v'   = velocity self ^+^ s_i ^+^ k_i ^+^ m_i
        p    = position self
        p'   = p ^+^ (v' ^/ speed)
    in self { position = p', velocity = v'}
```

A brief demonstration

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