



Intel Research
laboratory @ pittsburgh

Claytronics

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ourCS 10/07

Joint work with

Baker, Beckman, Campbell, Emre, Gibbons, Guestrin, Hoburg, Kufner,
Lee, Mowry, Pillai, Seshan, Sitti, Sukthankar, Veloso,
Kirby, Aksak, Ashley-Rollman, DeRosa, Karagozler, Funiak,

...

Additional Work done by: Robyn Badon, Christine Gingerich, B
Grigorian, Chris Cheung, Kate Ericson, Lene Mejlby, Michelle Doolittle,
& Allie Wehrman

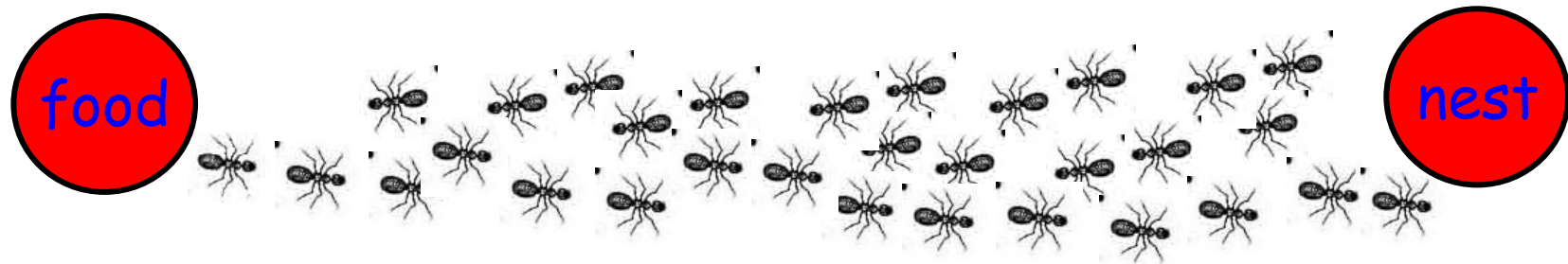
Programmable Matter



- A programmable material...
- ...with actuation and sensing...
- ...that can morph into shapes under software control...
- ...and in reaction to external stimuli

"Emergent Behavior"

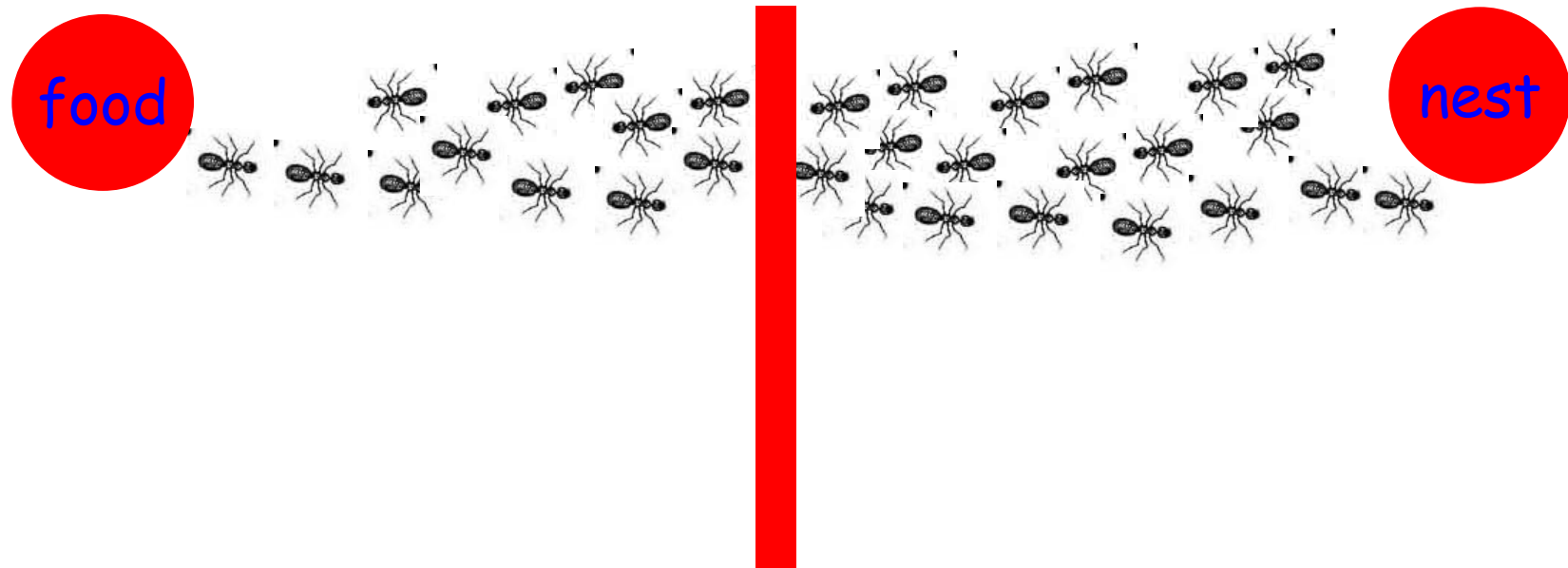
- Incredibly seductive
- Witness ants



- They proceed from nest to food and back via pheromone trail

"Emergent Behavior"

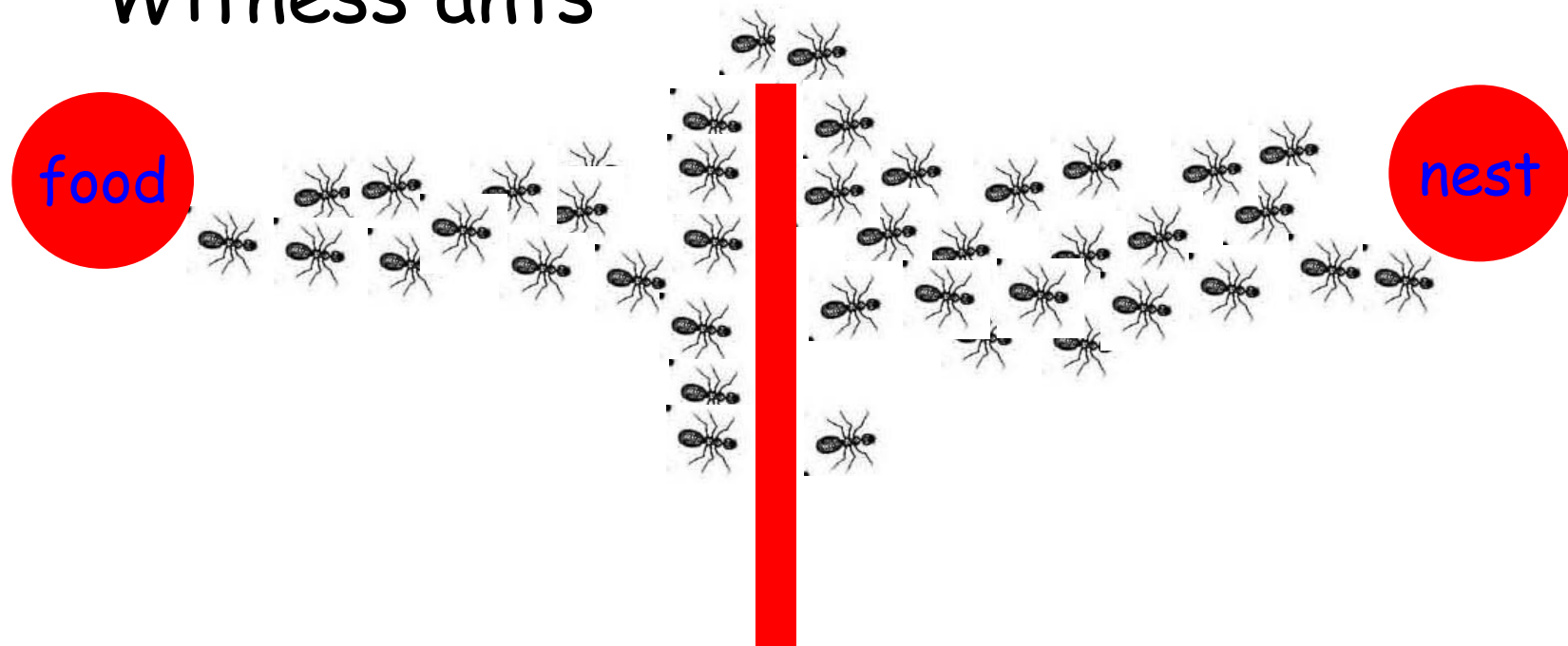
- Incredibly seductive
- Witness ants



- What happens when it is blocked?

"Emergent Behavior"

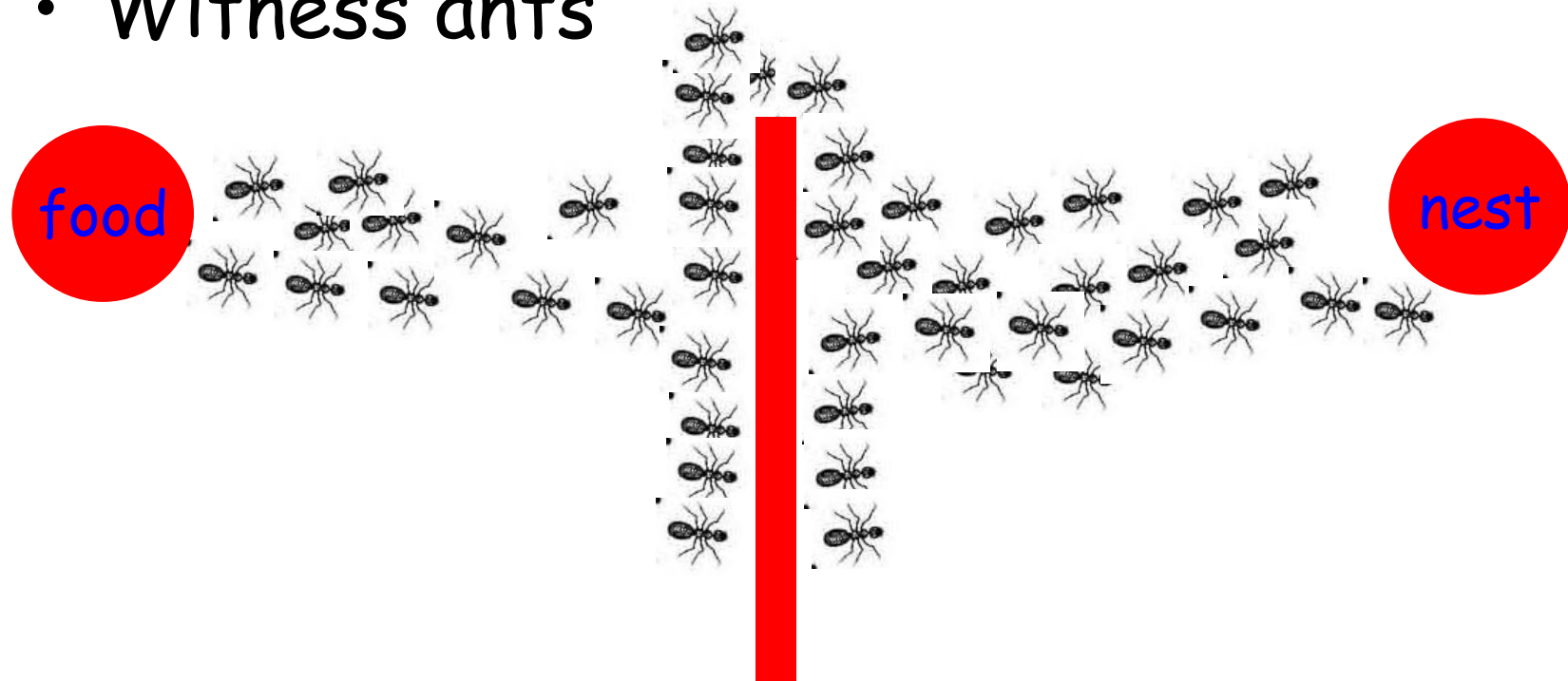
- Incredibly seductive
- Witness ants



- Ants that hit obstacle turn right or left randomly!

"Emergent Behavior"

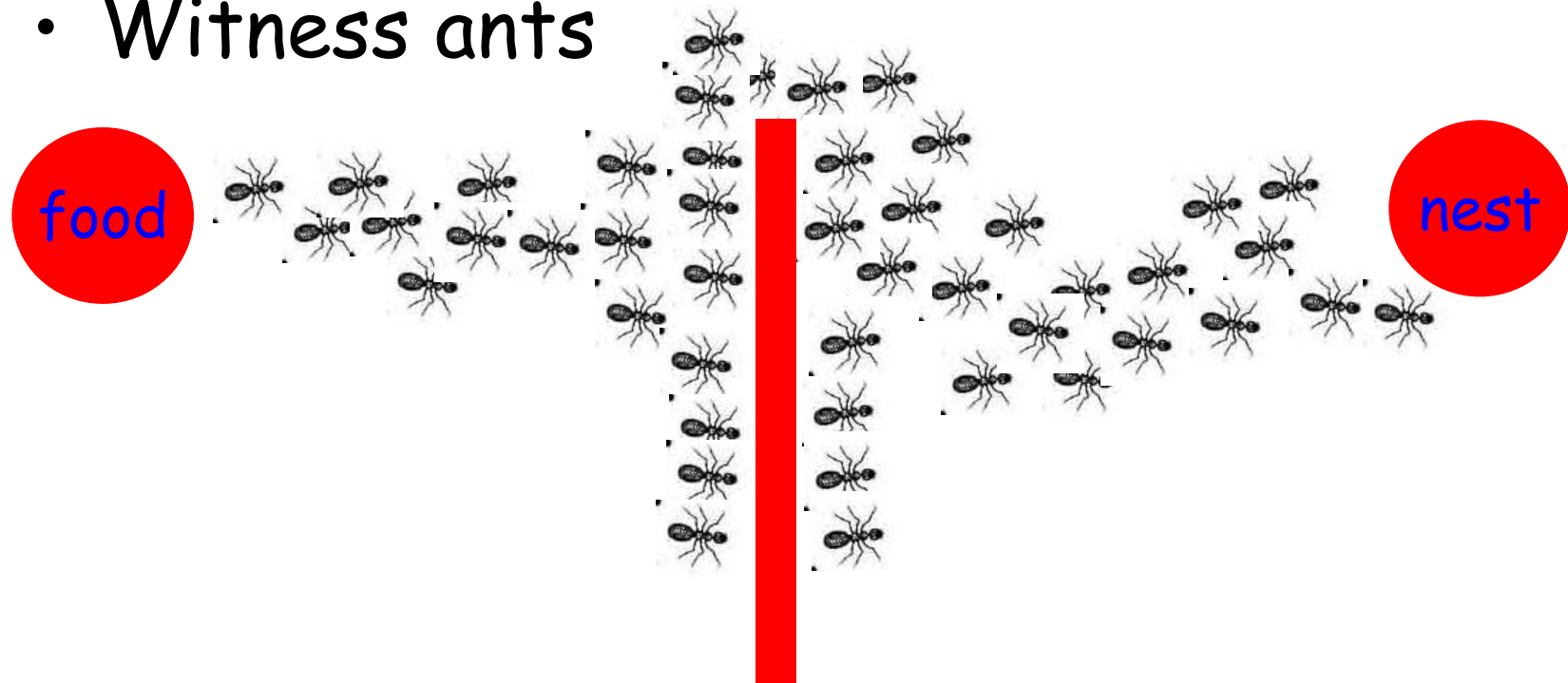
- Incredibly seductive
- Witness ants



- Ants prefer to follow a path with pheromones on it.

"Emergent Behavior"

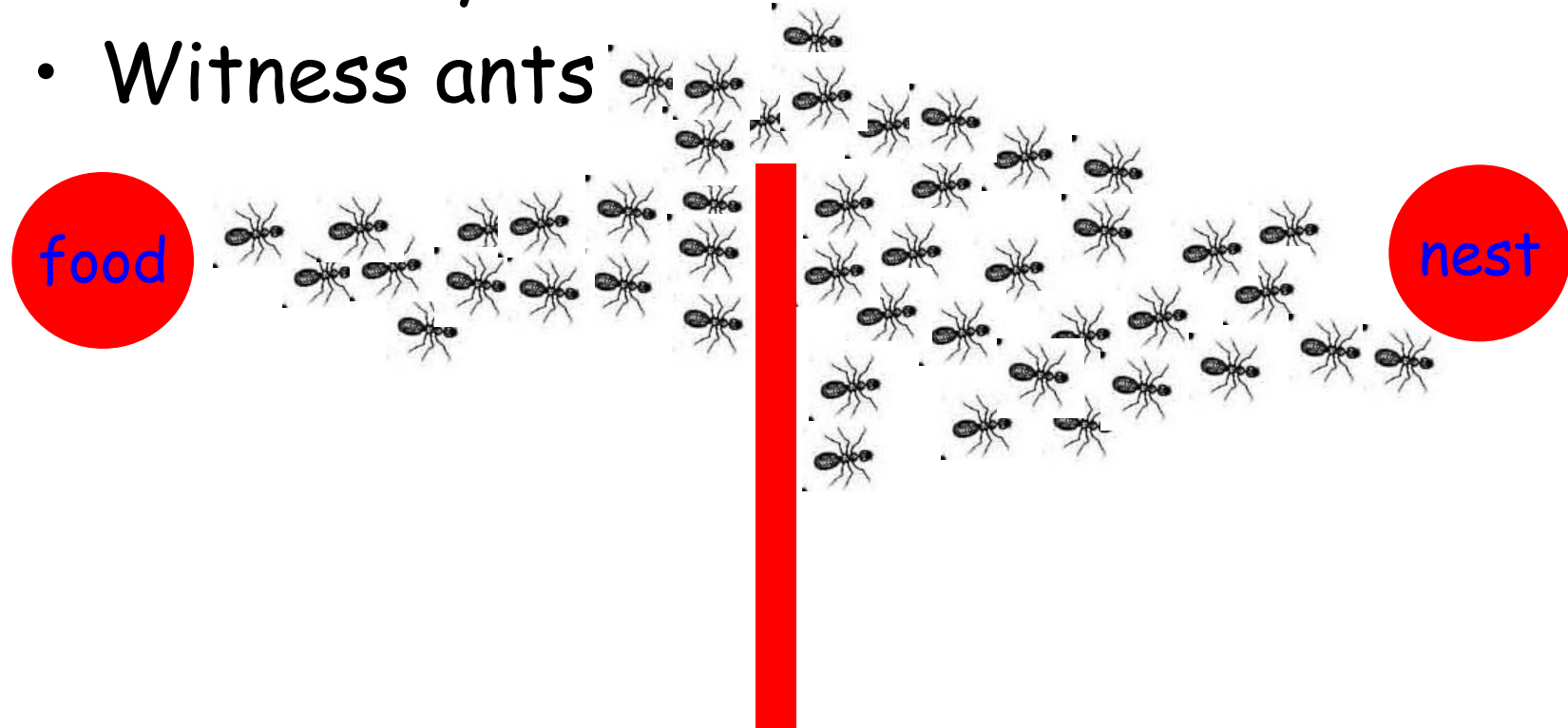
- Incredibly seductive
- Witness ants



- Shortest path has more pheromones on it

"Emergent Behavior"

- Incredibly seductive
- Witness ants

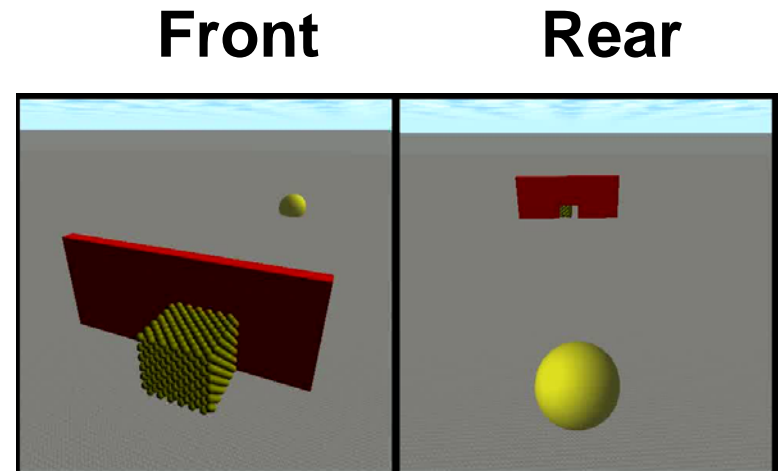


- Voila: They find the shortest path!

An Ensemble Program

- Simple Ensemble Movement:

```
moveAround( X, Y, Point ) :-  
  neighbor( X, Y ),  
  brightness( X, N ),  
  brightness( Y, M ),  
  vacant( Y, Point ),  
  N <= M.
```



- Attributes

- Ensemble level thinking
- Concise understandable program
- Scalable
- Amenable to proof
- Robust to failure and environmental uncertainty

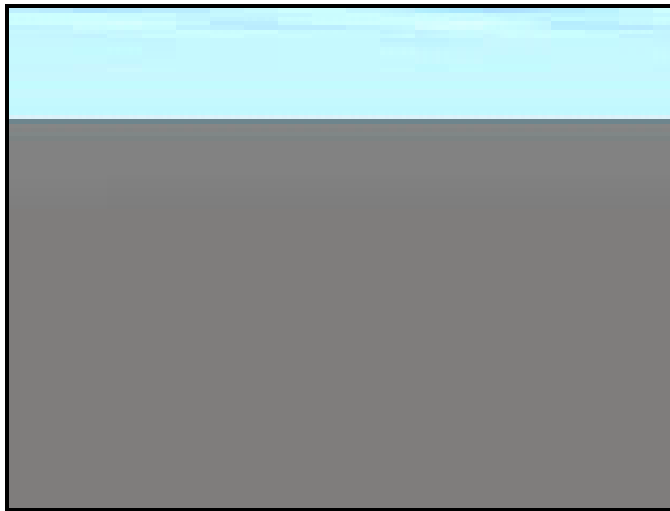
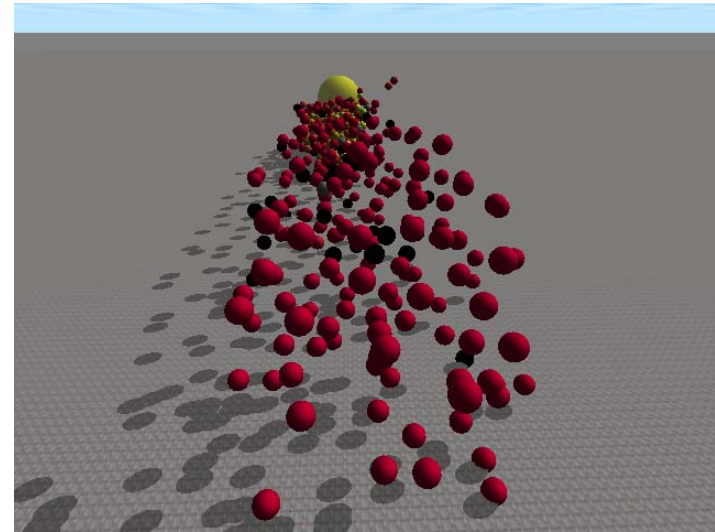
- Our Goal: No one left behind!

Three different approaches

- Global gradient
 - Lightest to darkest of the entire mass
- Neighbor gradient
 - Lightest to darkest based on nearest neighbors
- Grouping gradient
 - Keeping neighbors controlled by a leader in self-contained moving groups

Light/Dark Gradient

- Determine method of movement based on distance from the light



Another take on Gradient

- Deciding gradient based on nearest neighbors.



Meta-Modules

- Creating groups to avoid atoms being left behind...

