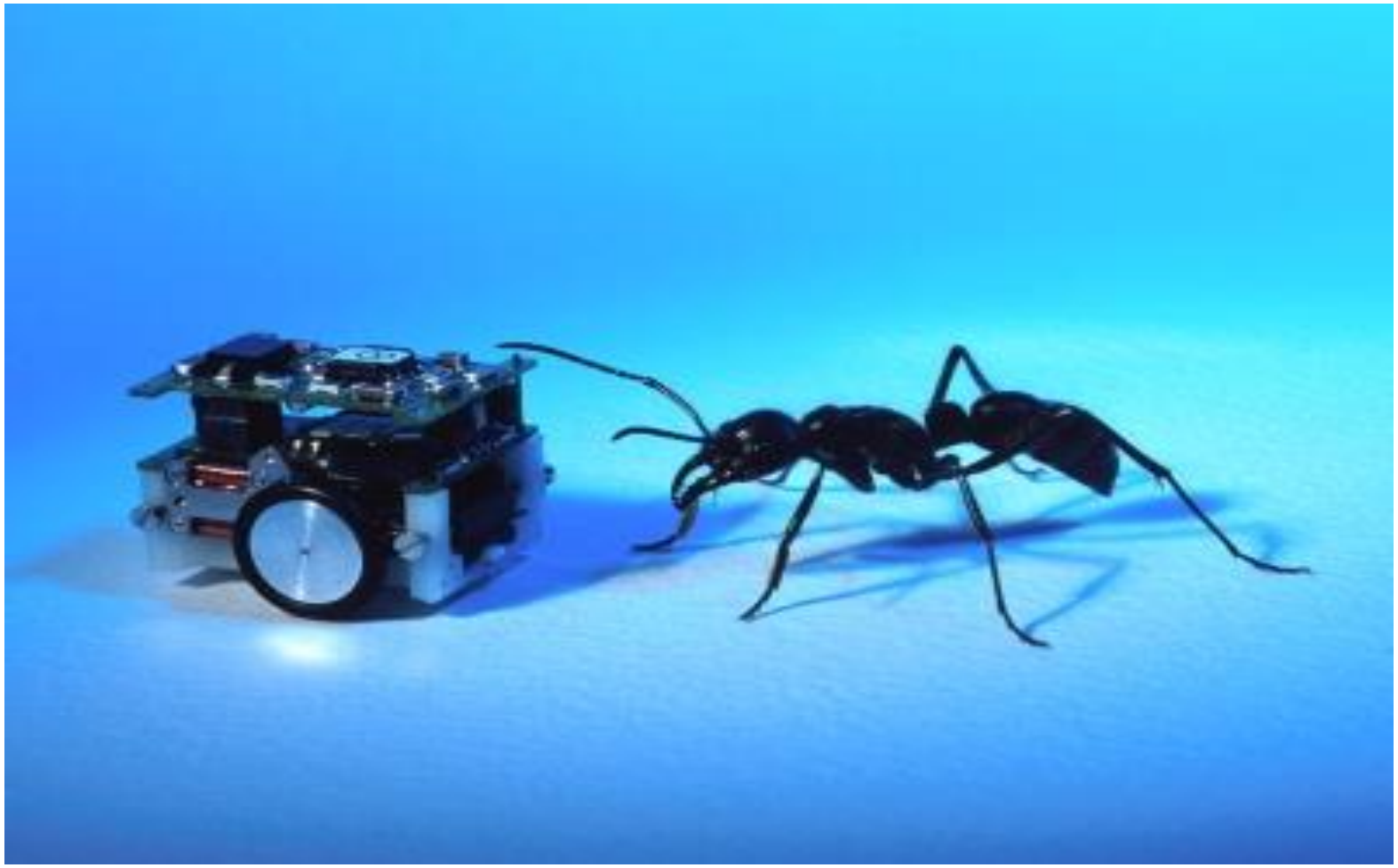

SWARM INTELLIGENCE

SWARM INTELLIGENCE

Ross Moon

CSCI 446: Artificial Intelligence

OVERVIEW

- What is Swarm Intelligence
- Swarms in Nature
  - Ants
  - Birds
- Ant Colony Optimization
- Particle Swarm Optimization

WHAT IS SWARM INTELLIGENCE?

Swarm intelligence is how individuals, knowingly or not, cooperate together to achieve a goal.

ROOTS IN MODELS OF SOCIAL INSECT BEHAVIOR

- Ants searching for food.
- Birds flocking together.
- Termites building nest.
- Bacteria foraging for food.

SWARM INTELLIGENCE DEFINED

- Useful behavior that emerges from the cooperative efforts of a group of individual agents;
- … in which the individual agents are largely homogeneous;
- … in which the individual agents act asynchronously in parallel;

SWARM INTELLIGENCE DEFINED, CONT.

- in which there is little or no centralized control;
- .. in which communication between agents is largely effected by some form of stigmergy;
- … in which there ‘useful’ behavior is relatively simple (finding a good place for food, or building a nest – not writing a symphony, or surviving for many years in a dynamic environment).

WHAT DO THEY HAVE IN COMMON?

- All move in groups to achieve a goal
  - Behavior of groups is special to the group
- Individuals in group act together in unison
  - Byproduct of local control of individuals
- No global control of group.

ANTS IN NATURE

- Ants individually are not so clever
  - Colony of ants can be
- Ants excel at finding the shortest and safest path to food
- Ants searching for food inspired algorithm
  - Ant Colony Optimization (ACO)

ANTS IN NATURE

- Ants are naturally stochastic
- Have no direct forms of communication
- Communicate via
  - Touch
  - Sound
  - Pheromones
- Type of communication: Stigmergy

STIGMERGY

- An agent's actions leave sigs in the environment. These signs are later sensed by other agents, which in turn determine and incite their subsequent actions.
- Greek words "*stigma-ergon*"
  - Meaning "*mark-action*"

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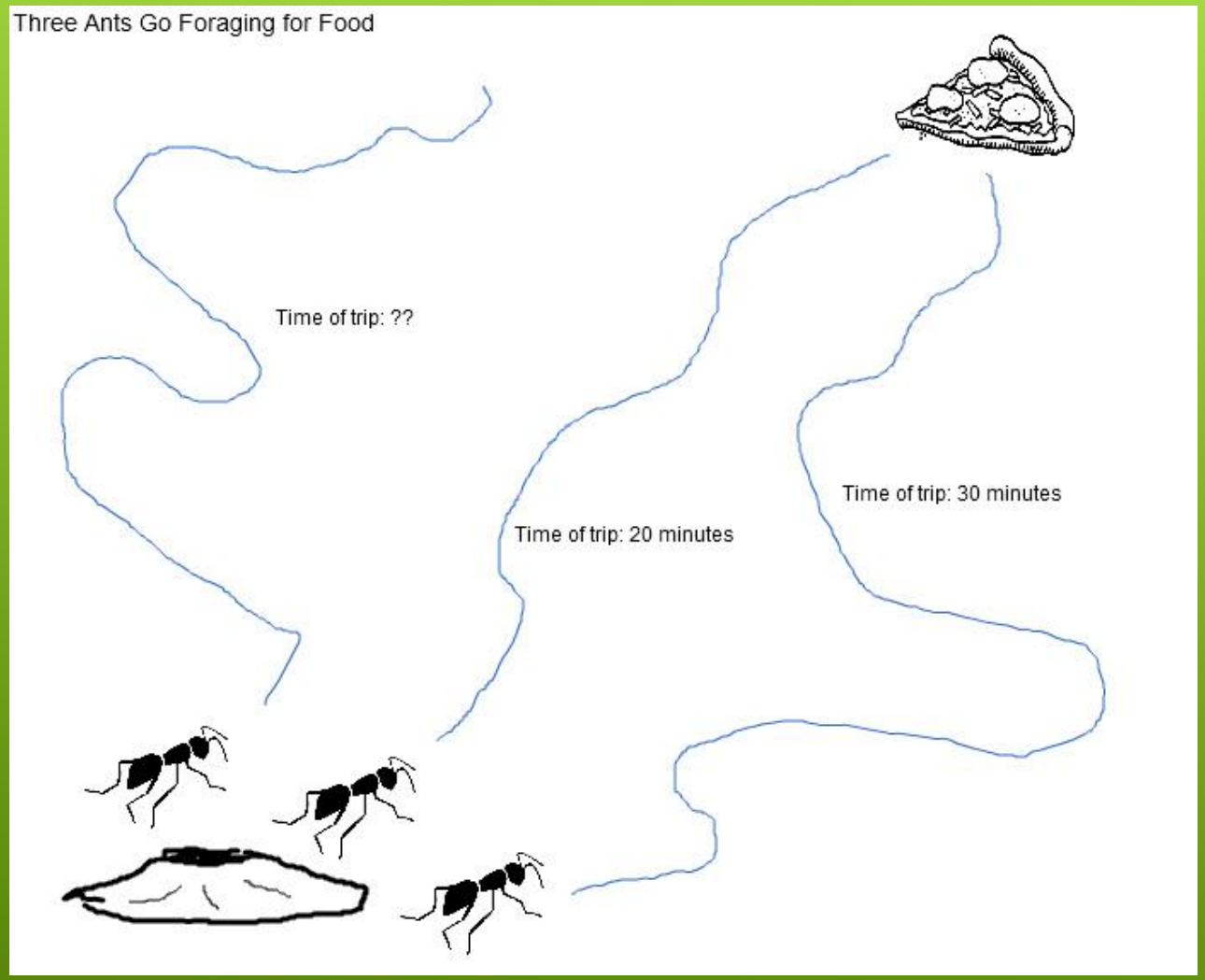


HOW ANTS GET IT DONE

- Ants leave pheromone trails
- Strength of trail influences other ants to take path
- Ants are still stochastic by nature

BIRDS IN NATURE

- Birds flock together
  - Protection
  - Search for Food
  - Migration
- Prime example
  - Starling Murmuration

STALING MURMURATION

- https://www.youtube.com/watch?v=eakKfY5aHmY

REYNOLDS RULES: RULES OF A FLOCK

- **Cohesion**: steer towards the mean position of others, thus staying close to other flock mates
- **Alignment**: steer towards the mean heading of others and match velocity
- **Separation**: steer to avoid coming to close to others and avoid collisions

ANT COLONY OPTIMIZATION (ACO)

- Like ants in nature – excel at finding shortest path
- Excellent for problems like Traveling Salesman

$$p_{ij}^{k} = \begin{cases} \dfrac{[\tau_{ij}]^{\alpha}[\eta_{ij}]^{\beta}}{\sum_{k \in \text{feasible}_k}[\tau_{ik}]^{\alpha}[\eta_{ik}]^{\beta}} & \text{if} \quad j \in \text{feasible}_k \\ 0 & \text{otherwise} \end{cases}$$

- $[t_{ij}]$ – reprents the pheromone trail from i to j.
- $[h_{ij}]$ represents the heuristic value from i to j.
- a and β are influence weights of pheromones and heuristic

$$\Delta\tau_{ij}^{k}(t) = \begin{cases} {}^{1}/_{L^{k}(t)} & , if\ arc(i,j) \in T^{k}(t) \\ 0 & , \quad otherwise \end{cases}$$

- L – weight of the edge between nodes i and j.
- t – current iteration

PARTICLE SWARM OPTIMIZATION

- Follow Reynolds rules
  - **Cohesion**
  - **Alignment**
  - **Separation**
- Add new rule
  - Attraction to a target
  - Fitness function to determine how good a place is to be

PARTICLE SWARM DYNAMICS

$$\Delta v(t) = F\left(x(t-1), \Delta v(t-1), p_b, p_g\right)$$

- Particle acceleration can be a function of F
- Particle position x(t)
- Pb – particle's best position
- Pg – particle's neighborhood's best position

PARTICLE SWARM VELOCITY UPDATE

$$v(t) = v(t-1) + \Delta v(t-1)$$

Velocity at time t is velocity at time t-1 plus the acceleration value

PARTICLE SWARM MAX VELOCITY

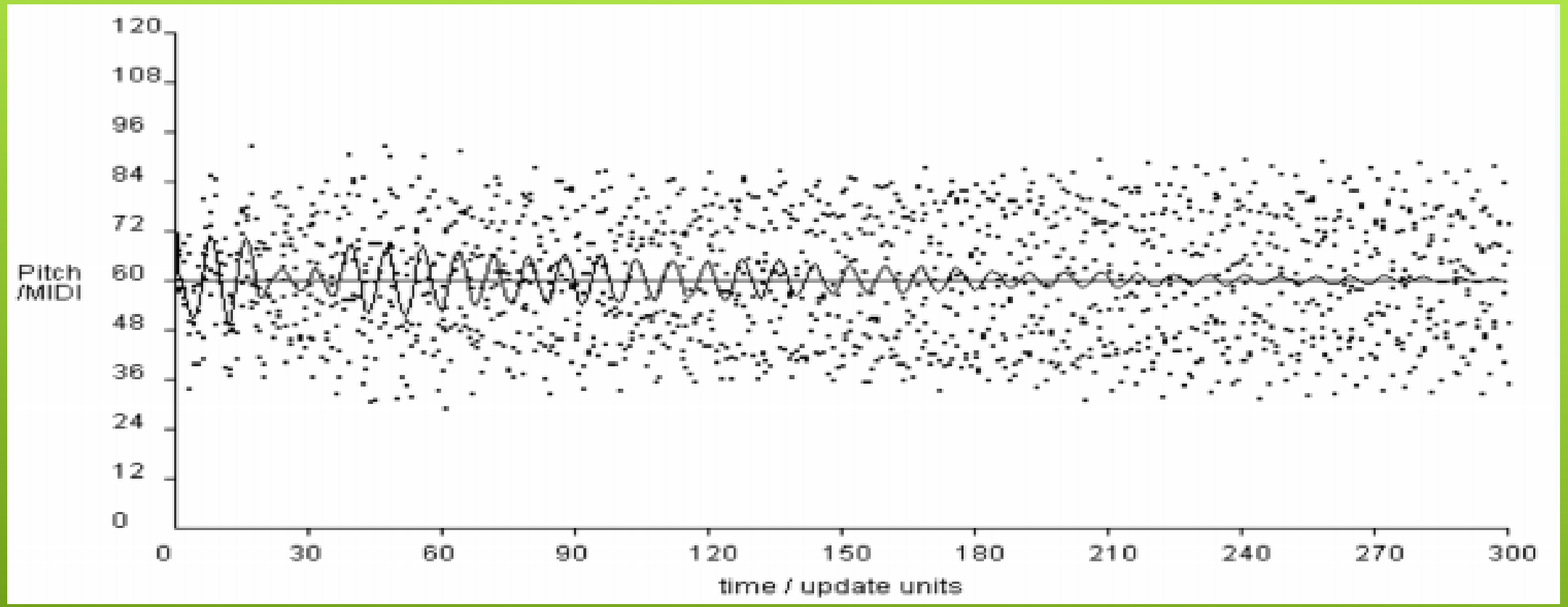
$$v(t+\varepsilon) = v(t) + \theta\left(\left|\left(v(t)/v_{max}\right)\right| - 1\right)\left(v_{max} - v(t)\right)$$

- Provides nonlinear damping force
- Applied instantaneously
- Effect of limiting the velocity

PARTICLE SWARM POSITION UPDATE

$$x(t) = x(t-1) + v(t)$$

- Particle position at time t is position at time t-1 plus velocity values



Center of swarm over time is plotted, and shows how the particles oscillate around the target

Eventually converge

CONCLUSION

- Nature inspired algorithms
- Advancement in robotics
- Used in Entertainment industry
  - Batman Returns, Lion King, Lord of the Rings
- Very good at solving specific problems that fit swarm behavior