Performance of Digital Pheromones for Swarming Vehicle Control

Pheromone logic can be used for several types of surveillance and target acquisition and tracking scenarios. The study demonstrates the effectiveness of these pheromone algorithms for these scenarios.

Digital pheromone

1. Deposited and withdrawn pheromone from an area. (Information fusion and aggregation).
2. Evaporated over time. (Forget old information = Truth maintenance).
3. Propagated from a place to its neighboring places. (Information diffusion and dissemination).

A digital pheromone represents information about the system. Different “flavors” of pheromones convey different kinds of information. Digital pheromones exist within in an artificial space called a pheromone map. The map is composed of an arbitrary graph of place agents.

There are 2 types of agents:

- Walkers :
  - Controls a single platform in the swarm.
  - Deposits, withdraws, and reads pheromones in the map.
  - Uses that information to make movement and action decisions.
  - Read sensory and other telemetry from the platform and issue commands to control its actions.
- Avatars :
  - Represent the other entities (friendly, enemy, neutral) in the environment.
  - Deposit, withdraw, and read pheromones in the map ➔to predict the unit next move.
  - Receives information :
    - type
    - location
    - heading
    - speed
    - …

    ↳ To estimate the location of the unit between contacts.

Pheromone Equations are introduced in 3.3:

- The first equation describes the evolution of the strength of a single pheromone flavor at a given place agent.
- The second fundamental equation describes the propagation received from the neighboring place agents.

Algorithms global descriptions

Each pheromone flavor has 4 parameters:

- Update cycle time
- Propagation factor
- Evaporation factor
- Minimum place agent pheromone level (threshold)

Description and pheromone equation for each algorithm

- 4.1 Surveillance and Patrol Algorithm.
- 4.2 Target Acquisition Algorithm.
- 4.3 Target Tracking Algorithm.

Experiments and results

- 5.1 Surveillance Coverage Performance.
- 5.2 Target Acquisition
- 5.3 Discontinuous Area Surveillance
- 5.4 Intermittent Tracking
- 5.5 Target Cueing

Real Scenario:

The demonstration used:

- Four robots
- A mock urban area
- Two Unmanned Air Vehicles (UAVs) controlled by pheromone technology

The demonstration focused on the swarming algorithms that control and coordinate the behaviors of the heterogeneous mix of vehicles.

Pheromone algorithms controlled and coordinated the flight of the two UAVs as they performed continuous surveillance over an urban area looking for potential adversaries. The two air units worked together to ensure even, thorough, and continuous coverage of all areas in the surveillance region while avoiding any collisions. They also provided patrol coverage of a mock convoy as it moved through the area.

While the UAVs surveyed a broad area over the airfield, the ground robots surveyed and patrolled around some mock buildings set up for the demo. During the demonstration, one of the ground robots failed. The other ground robots were able to dynamically readjust their patrol patterns to accommodate the missing unit without any intervention by the operator. This unplanned event helped to demonstrate the robustness of these algorithms to unexpected events.

The demonstration showed cooperative behavior between the air and ground units when the identity of a potential adversary detected by one of the UAV's was automatically confirmed by one of the ground robots with a special sensor capable of target identification.

The operator simply gives a high level command to the whole swarm, such as "survey this area and track any identified targets" or "patrol around this convoy". The robots autonomously configured themselves to determine which robot would perform what task in order to accomplish the overall objective.