

Programming Micro- Aerial Vehicle Swarms with Karma

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Karma

- Is a 'Micro-aerial vehicle system architecture'
- Seeks to simplify programming/deployment of swarms of "Micro-aerial Vehicles" (MAVs)
- MAV Assumptions:
 - Short flight time (order of several minutes)
 - No inter-vehicle communication
 - Deployed in large numbers
 - Applications require coverage of a certain operation
 - MAV operations are simple and often stochastic in nature
 - Operations are location agnostic

Example Application: Alfalfa Crops

- Monitor Alfalfa crop for diseases
- Monitor Alfalfa crop for pests
- Monitor Alfalfa crop for blooms
 - In the case of the Alfalfas blooming, pollinate them.

Karma - Hive-Drone Architecture

- Application is composed of processes
- Process composed of:
 - Action (Runs)
 - Uses
 - Yields
 - Progress
 - Activated when
- Hive coordinates drone sorties
- Drones perform the action on a particular region
 - Generate information in the course of conducting their sortie
 - Contribute to the Hive's datastore upon return.

Karma - Example Application

```
process MonitorBloom
  runs RandomWalkFlowerSearch
  uses ()
  yields ('bloom_obs', 'bloom_det')
  activated when ('bloom_obs':12h)
  progress := ('bloom_obs':12h /

process MonitorPests
  ...

process MonitorDisease
  ...

process Pollinate
  runs RandomWalkPollinate
  uses ('bloom_det')
  yields ('pollinated')
```

Karma - Details

Primary components

- Scheduler

- Determines priority of process-region pairs
- Calculate progress per drone sortie from historical data. Bootstrapping problem.
- Service level is: remaining drone sorties for region-process pair over all remaining drone sorties

- Dispatcher

- Dispatches according to scheduler, based on available drones, dispatch policy
 - Greedy Dispatch
 - Continuous Dispatch
- Dispatches: (available drones) * (Service level)

Simulation

- JBullet, Java 6 d.o.f rigid body simulator
- Karma implemented as standalone Java, interfaces with MAV through dispatch driver
- Virtual MAV
 - 40-50 second sortie. 2 minute charge time
 - Capable of supporting various sensors
 - accelerometer, gyroscope, range finder, etc.
- Can simulate wind, hardware failures etc.

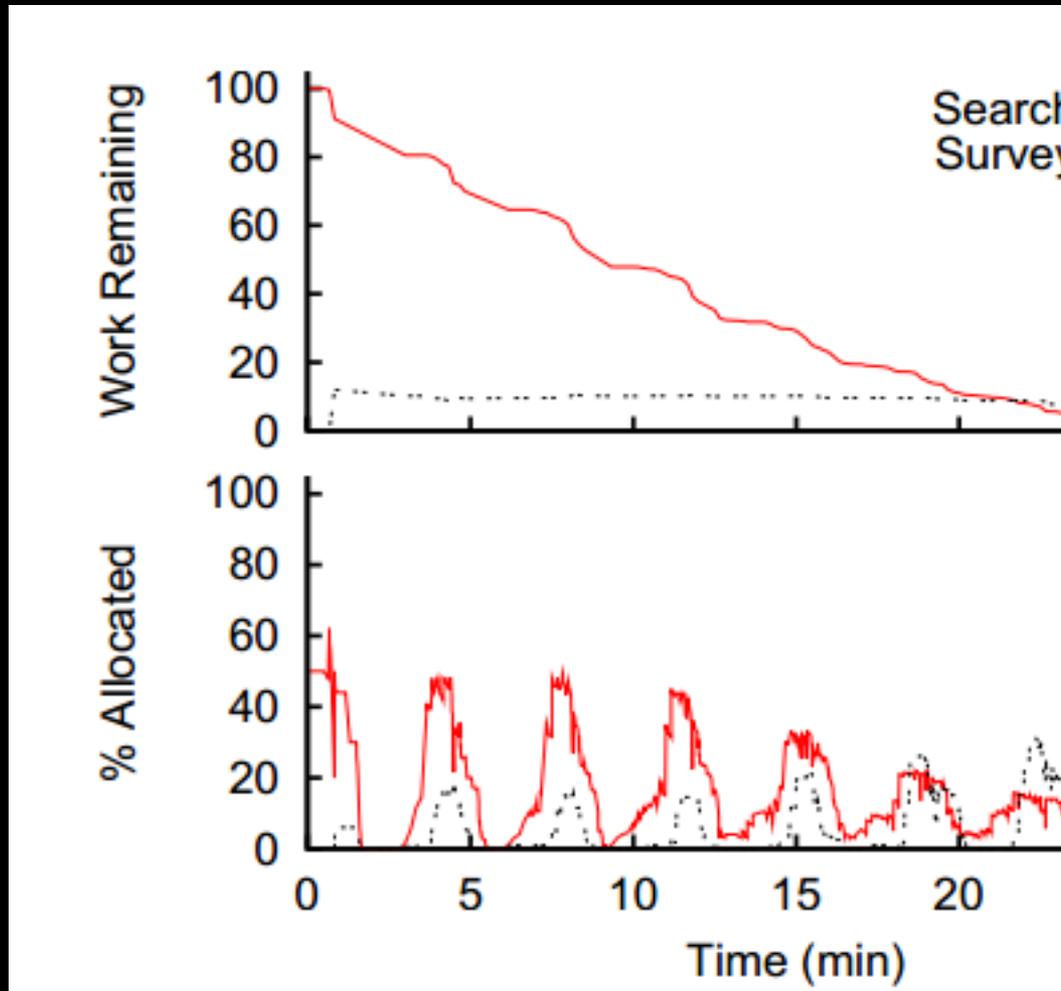
Simple Simulation - Walkthrough

```
process Search
  runs RandomWalkSearch
  uses ()
  yields ('obs', 'feature')
  activated when ('obs' < 250)
  progress := ('obs' / 250)

process Survey
  runs RandomWalkSurvey
  uses ('feature')
  yields ('studied')
  activated when ('feature' > 0)
  progress := (if isNull('feature')
               then 1
```

- No hardware failures, or adverse conditions
- 200 drones. 75 x 75 meter virtual region
- Circular 'feature' at (15, 15) with radius 10 meters.

Walkthrough - Results



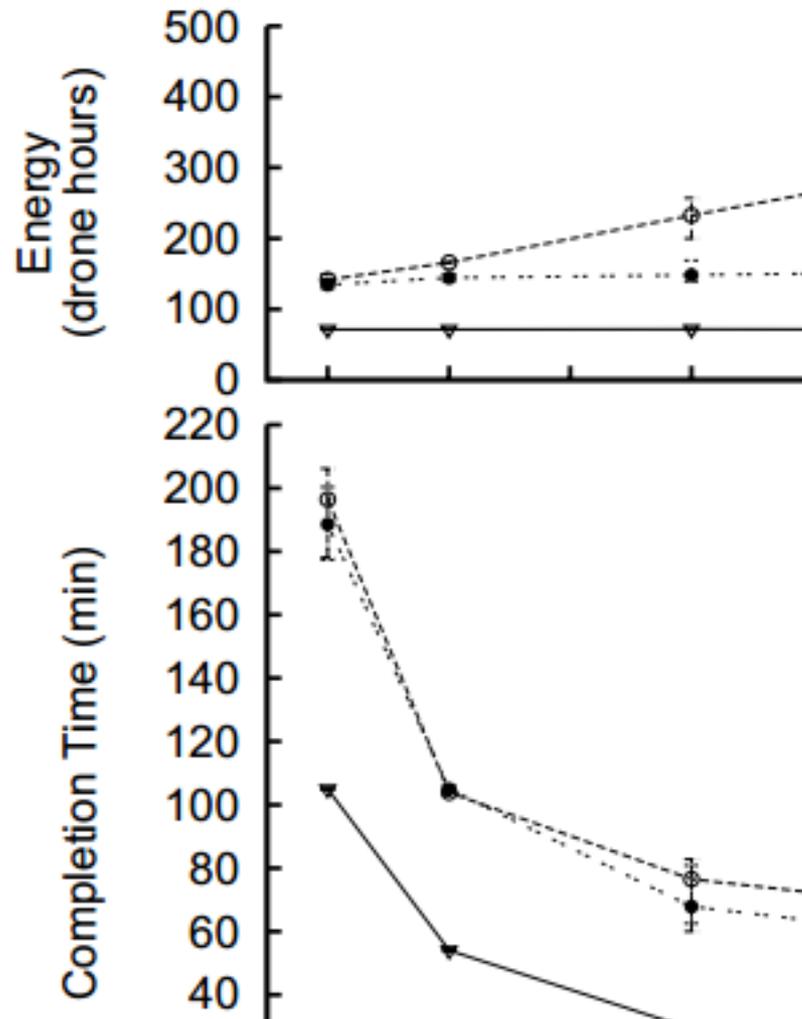
- Greedy Dispatch results in 'Wave' dispatches
- Bootstrapping is visible in first wave
- Since 'action' is left as a call, not clear how exactly 'feature' are added by the MAV

Alfa Simulation - Evaluation

Parameters

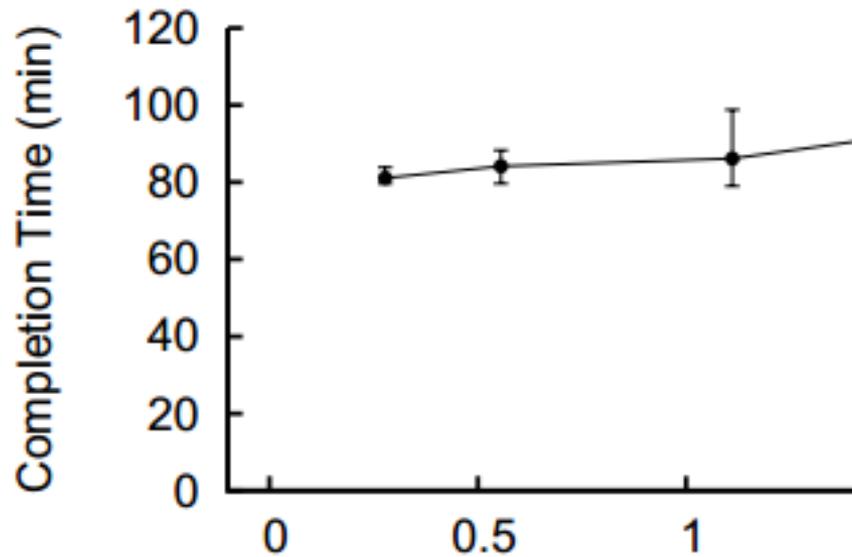
- 1 acre alfalfa field (63 x 63 meters)
 - 6x6 region grid in Karma
- Hive placed outside the field
- MAV
 - 5 minute charge time. 2 minute sortie time
 - 2 meters/second cruise speed
- Continuous dispatch policy (10 second intervals) unless otherwise noted

Dispatch Policy - Evaluation



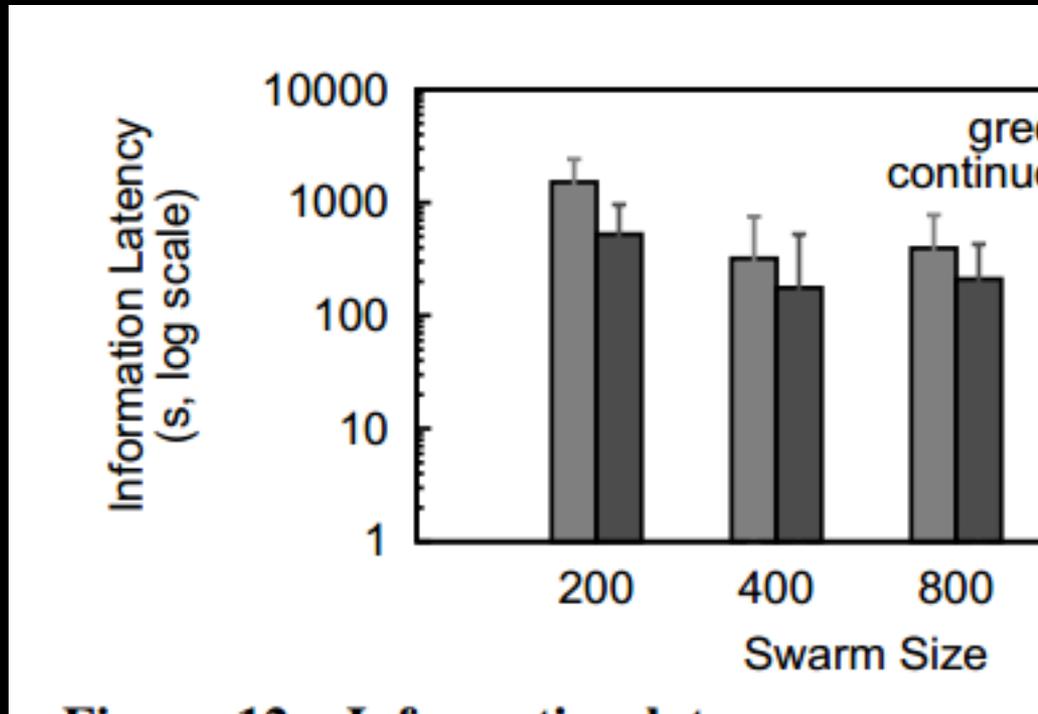
- Offline is theoretical lower limit
 - Has immediate drone information
- Can complete the task with no recharging with 850 drones
- Performance difference between Karma and offline attributable to bootstrap dispatch, and information muling

Failure Resilience



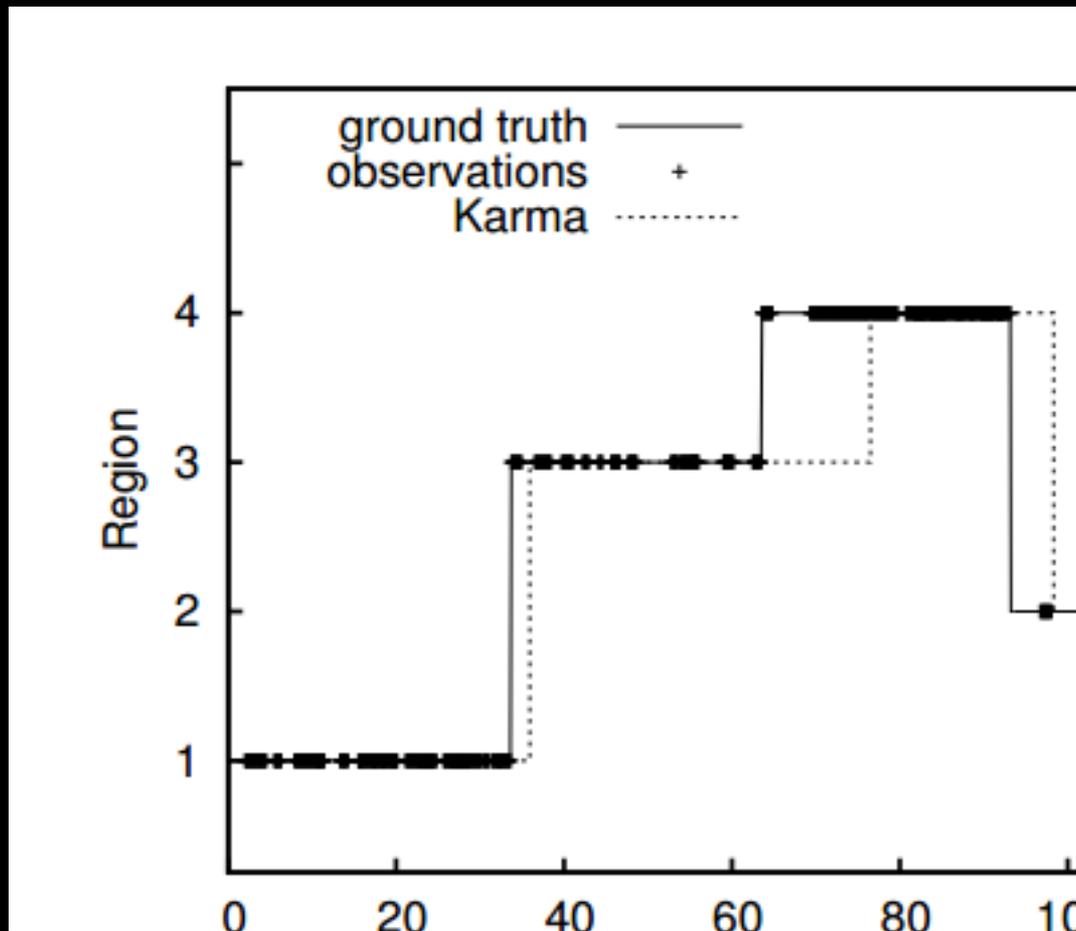
- Acceptable degradation for small failure rate.
- Authors' bring up adaptability to region dependant failure (wind, etc); Could cause catastrophic failure?

Information Latency - Evaluation



- Information latency for a single region-process pair...
 - Dependant on region location?

Hardware in Loop - Evaluation



- Use remote controlled mCX2 helicopter
- 20 second sorties
- Not very informative evaluation.
- How big is the space, regions?

Discussion

- Hive-Drone model seems promising
- 'Process', 'action', 'uses' model seems appropriate, effective
- Limited generality of applications
 - How many applications could not be described with Karma?
 - How many could?
- Limited evaluation.