A Signal-enhanced swarm of multirotor UAVs for surveys in poor GPS/GNSS wild areas

C. Stallo*, M. Ruggieri*
I. Manfredonia, G. Massari****

***University of Rome Tor Vergata - ITALY**
****AerialClick di Massari Srl, Brindisi - ITALY**

Rome, CASD
June 07th-08th, 2016

NATO Specialist Meeting on
"Swarm centric solution for Intelligent Sensor Networks"

Overview

1. Introduction
2. Swarm Intelligence Concepts
3. Drones Swarm
4. Navigation in harsh GNSS environment
5. Communication among Drones Swarm
6. (Large Bandwidth or no? EHF or lower frequencies?)
7. Conclusions

Introduction

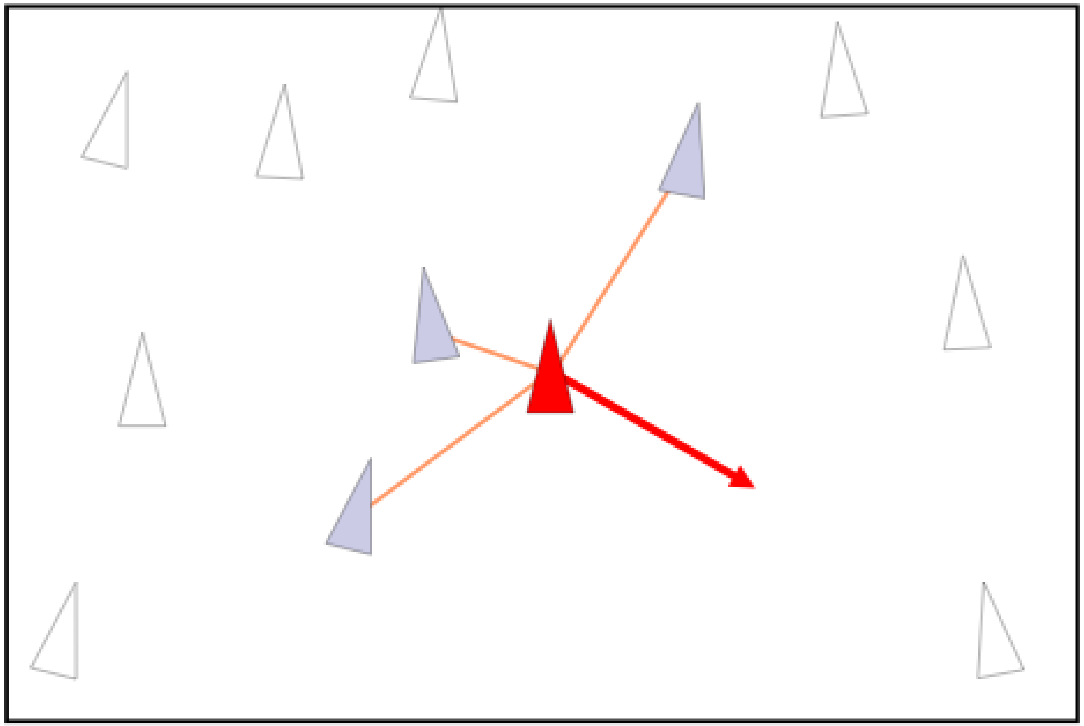
- Monitoring of wide wild natural areas sometimes is really important for natural preservation purposes so as for developing surveys where no manned terrestrial vehicles are allowed.
- Unmanned vehicles are precious means to discover and collect data in these peculiar situations, but loss of GPS/GNSS signal can make this strategy sterile and hard to be practised.
- This work aims at showing a preliminary drones swarm architecture where a leader UAV rules in case of loss of GPS/GNSS providing information about position and orientation to the rest of the swarm. A kind of flying temporary signal source for the continuity of the survey process is established in this way.

Swarming – Bird Flocking

- Bird Flocking
- “Boids” model was proposed by Reynolds
  - Boids = Bird-oids (bird like)
- Only three simple rules:
  - Collision Avoidance;
  - Velocity Matching;
  - Flock Centering.

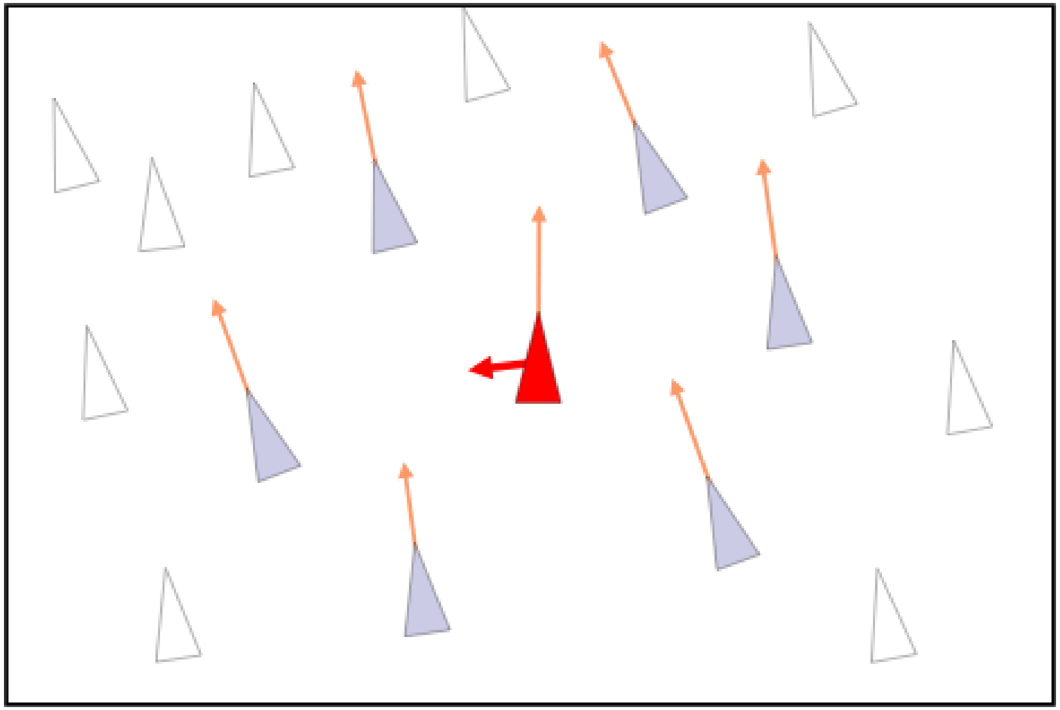
Collision Avoidance

- Rule 1: Avoid Collision with neighboring birds



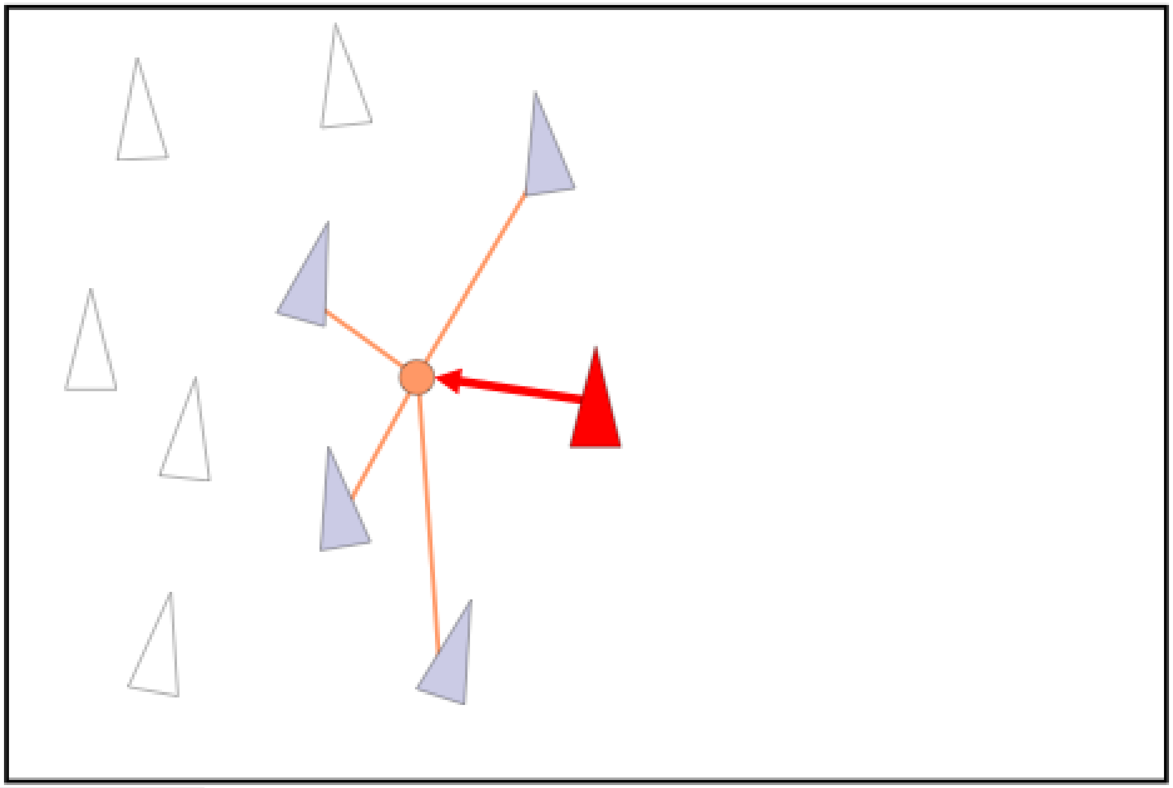
Velocity Matching

- Rule 2: Match the velocity of neighboring birds



Flock Centering

- **Rule 3**: Stay near neighboring birds



Swarming Characteristics

- Simple rules for each individual
- No central control
  - Decentralized and hence robust
- Emergent
  - Performs complex functions
- Learning from insects, swarming systems are:
  - Robust
  - Relatively simple

Swarm elements

Features	
Diameter	**250-300 mm**
Max Take Off Weight	**<2kg (ideally 300g)**
Payload	**No Payload**
Max flight time	**15-25 mins**

The short range UAVs composing the swarm have to be very light, ultra responsive, reliable, fast and resistant. They could have some points in common with racing models.

Navigation in Harsh GNSS Environment

- In a full vegetation environment the positioning accuracy significantly decreases since trees surrounding the receiving antenna may block the direct line-of-sight (LOS) to many satellites, hence reducing the visibility. The remaining signals have poor geometry and degrade the position accuracy.

Navigation in Harsh GNSS Environment

- Several existing techniques of multipath and NLOS (Not Line of Sight) mitigation may be categorized as hardware-based, signal processing in receiver and measurements domain. Their main limitations are usually related to cost, size, weights and power consumption.

- The common approaches to deal with the multipath problem through receiver-based techniques, such as the narrow correlators, do not bring the best improvement in the case of NLOS situations due to the absent of LOS signal.

- In post receiver techniques one way to solve the NLOS situation problem is to identify and exclude the associated measurements in the navigation algorithm, by using techniques such as consistency-checking (RAIM (Receiver Autonomous Integrity Monitoring)). This approach is not well adapted to positioning in harsh environments, when only degraded measurements may be available.

Navigation in Harsh GNSS Environment

- Few works exist in the literature on constructive use of NLOS signals.

- One option is to approximate the pseudorange errors model of NLOS measurements so that they may still be usable for positioning. The bias can be treated either as a **random variable**, if a statistical characterization is available or as a deterministic quantity if it is somehow known or predictable.

- The measurement errors distributions depend on the observation window size. Over a short observation period, pseudorange errors can be modeled by a Gaussian distribution, with time-varying mean and variance.

Navigation in Harsh GNSS Environment

- A powerful solution is to compare GNSS measurements with data acquired by other instrumentation (Fiber Optic Gyroscope (FOG) or MEMS (Microelectromechanical system) gyroscope) to ensure the accuracy and integrity required by critical applications.

- In order to reduce mission costs, it is more convenient to install this device only in a UAV leader, which communicates, in the case of quasi absence of GNSS signal, the information about the asset of the swarm to the other drones.

- Therefore, we have a drones swarm in normal operation that, in the case of quasi-absence of GNSS signal, has a leader able to orient the flock.

Communication among swarm drones

- Another issue is the communication between the nodes of the UAV swarm network.

- Scenarios in open environments in which mobile nodes must move to ensure connectivity have been studied, but the tasks were limited to either maintain network connectivity, or establish connectivity between two fixed points.

- Distributed sensing over extended periods of time is necessary for environmental monitoring.

Communication among swarm drones

- To keep the per-unit costs low, we will use a heterogeneous system of drones: one drone will be equipped with long-range communication devices, while the others will only be equipped with relatively short-range communication equipment.

- All drones will participate in task execution, and the drone with long-range communication capabilities will serve as gateways versus the Control Station through which operators can issue new instructions for defining or changing the mission objective.

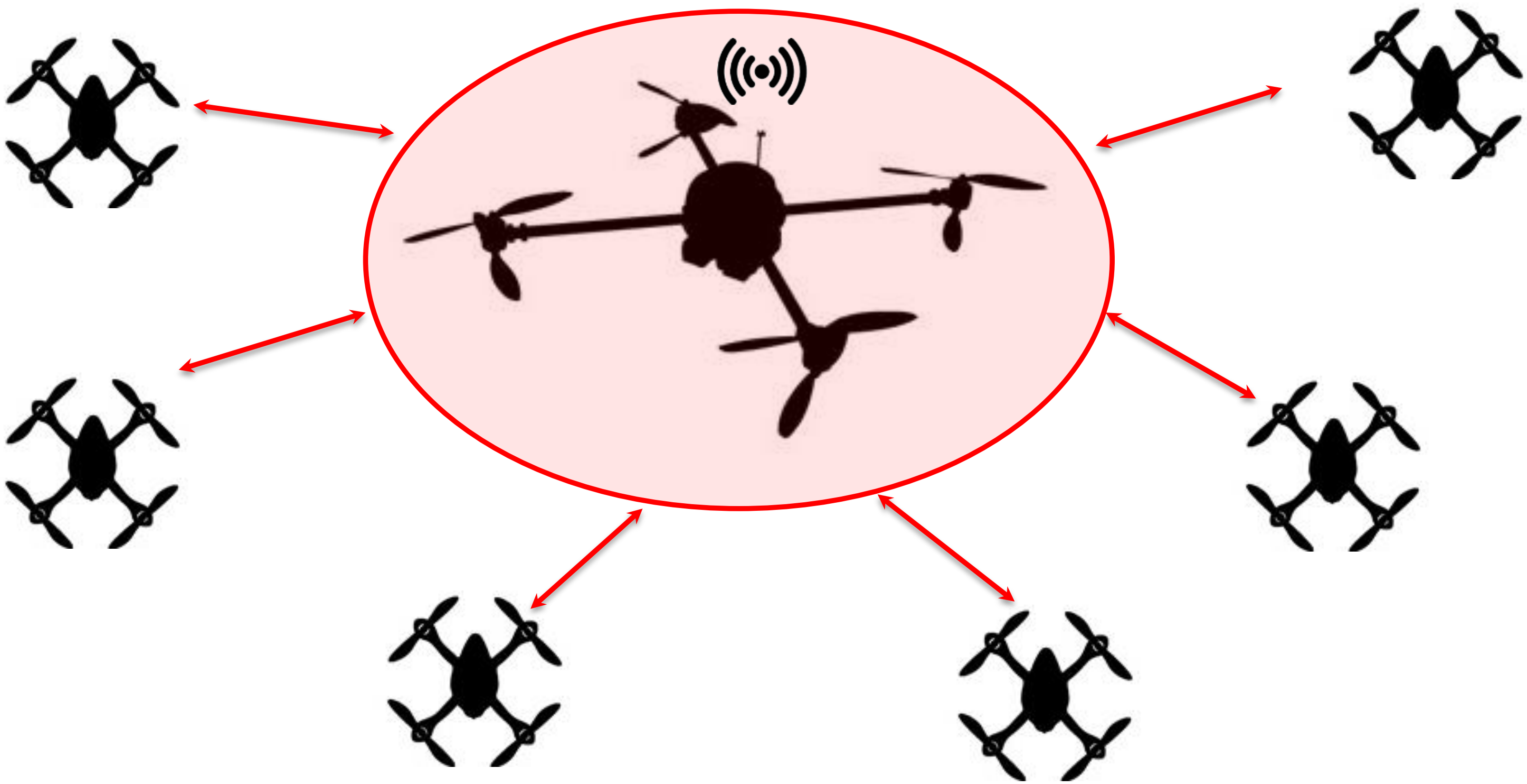
- Local drone-to-drone communication can be achieved through ISM (Industrial, Scientific, and Medical) bands (in particular [863-870] MHz or [902-928] MHz).

Leader drone

Features	
Diameter	Up to 1300 mm
Max Take Off Weight	Up to 7kg
Payload	Up to 12kg
Max flight time	30-50 mins

The leader of the swarm has to be a bigger model (a coaxial octacopter would be a proper choice to the conceived swarm) equipped with an embedded GNSS and sensitive sensors among which a MEMS gyroscope. Frame material has to be so light to allow almost 50 mins of autonomy

Swarm configuration



Large Bandwith or No?

- 60 GHz Communications?

- **High bandwidth radio transmission**
  - Frequency range appr. 58–64 GHz

  → **several GHz of bandwidth allocated wordwide for 60 GHz telecommunication**

- **Very high speed** wireless connections
  - theoretically up to **1 Gb/s**

- **Little interference**
  - Does not interfere with existing wireless systems;
  - Due to oxygen attenuation, **spatial capacity is high.**

- **Propagation**
  - Range: tens of meters indoors, up to 500/1000 m outdoors

- You can use **60 GHz bandwidth** for positioning (UWB) too. High Cost Equipment!!!

- **ISM** (Industrial, Scientific and Medical) bands (863.0 – 870.0 MHz 2400 – 2483.5 MHz in Europe) cannot be used for positioning, since the accuracy is not compliant with the mission requirements. COTS for communications!!!

AerialClick

Conclusions

- Monitoring of wide wild natural areas sometimes is really of vital importance for natural preservation purposes so as for developing surveys where no manned terrestrial vehicles are allowed.

- Unmanned vehicles are precious means to discover and collect data in these peculiar situations, but loss of GPS /GNSS signal can make this strategy sterile and hard to be practised.

- This work aims at showing a preliminary drones swarm architecture where a leader UAV rules in case of loss of GPS/GNSS providing information about position and orientation to the rest of the swarm. A kind of flying temporary signal source for the continuity of the survey process is established in this way.

Thank you!

Contact:
Ivano Manfredonia
e-mail: ivano.manfredonia@aerialclick.com